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MATHEMATICS

THE GENERALIZATION OF RICCI'S AND BIANCHI'S IDENTITIES FOR A CONNEXION IN THE COMPOUND MANIFOLD

By V. WAGNER

(Communicated by A. N. Kolmogoroff, Member of the Academy, 17. XII. 1944)

Consider a compound manifold $X_{n+(m)}$ (1) with a connexion of the class s determined by the coefficients of connexion $\Gamma^\alpha(u^c, \xi^\lambda, \xi^{(k)\lambda})$, where $\xi^{(k)\lambda} = d^{(k)}\xi^\lambda / dt^k$ $(k=1, \ldots, s)$. Let

$$\xi^\alpha = \xi^\alpha(t^1, t^2) \tag{1}$$

be the equations of a two-dimensional surface in the base X_n. Considering the representations of the local X_m's along an arbitrary curvilinear quadrangle $M_0(t^1, t^2)$, $M_1('t^1, t^2)$, $M_{12}('t^1, 't^2)$, $M_2(t^1, 't^2)$ formed by the coordinate lines, we obtain a point transformation in the local $X_m(M_0)$

$$'u^\alpha = \underset{12}{H^\alpha}(u^c, t^1, t^2, 't^1, 't^2) \tag{2}$$

which belongs to the group of holonomicity at the point M_0. Since

$$\underset{12}{H^\alpha}(u^c, t^1, t^2, t^1, 't^2) = \underset{12}{H^\alpha}(u^c, t^1, t^2, 't^1, t^2) = u^\alpha$$

we have that the first partial derivatives of the functions $\underset{12}{H^\alpha}$ with respect to the variables $'t^1$, $'t^2$ evaluated for $'t^1 = t^1$, $'t^2 = t^2$ will vanish. Similarly we obtain that of all partial derivatives of the second order evaluated for $'t^1 = t^1$, $'t^2 = t^2$ only the mixed derivative can be different from zero.

It can be shown that

$$\left(\frac{\partial^2 \underset{12}{H^\alpha}}{\partial' t^1 \partial' t^2}\right)_{\substack{'t^1 = t^1 \\ 't^2 = t^2}} = -\underset{12}{R^\alpha} \tag{3}$$

where we denote

$$\begin{aligned} \underset{12}{R^\alpha} &= \frac{\partial \underset{2}{\Gamma^\alpha}}{\partial t^1} - \frac{\partial \underset{1}{\Gamma^\alpha}}{\partial t^2} + \underset{1}{\Gamma^\alpha_c}\,\underset{2}{\Gamma^c} - \underset{2}{\Gamma^\alpha_c}\,\underset{1}{\Gamma^c} \\ \underset{z}{\Gamma^\alpha} &= \Gamma^\alpha(u^c, \xi^\alpha(t^1, t^2), \underset{z}{\xi^{(k)\alpha}}(t^1, t^2)) \end{aligned} \tag{4}$$

$$\underset{z}{\xi^{(k)\alpha}} = \frac{\partial^k \xi^\alpha}{\partial t^{zk}}; \quad \underset{z}{\Gamma^\alpha_c} = \frac{\partial \underset{z}{\Gamma^\alpha}}{\partial u^c}; \quad z = 1, 2; \quad k = 1, \ldots, s$$

If the connexion is linear, *i. e.* $\Gamma^\alpha = \Gamma^\alpha_\alpha(u^c, \xi^\lambda)\,\xi^{(1)\alpha}$, we have

$$\underset{12}{R^\alpha} = \underset{\alpha\beta}{R^{\cdot\cdot\cdot\alpha}}\,\underset{1}{\xi^{(1)\alpha}}\,\underset{2}{\xi^{(1)\beta}} \tag{5}$$

where

$$R^{\cdot\cdot\alpha}_{\alpha\beta} = \frac{\partial \Gamma^{\alpha}_{\delta}}{\partial \xi^{\alpha}} - \frac{\partial \Gamma^{\alpha}_{\alpha}}{\partial \xi^{\beta}} + \Gamma^{\alpha}_{\alpha c}\Gamma^{c}_{\beta} - \Gamma^{\alpha}_{\beta c}\Gamma^{c}_{\alpha} \tag{6}$$

Considering the representation of the local X_m's along the way $M_0M_2M_{12}M_1M_0$, we obtain a point transformation

$$'u^a = \underset{21}{H^a}(u^c,\ t^1,\ t^2,\ 't^1,\ 't^2) \tag{7}$$

which is inverse to the point transformation (2). Similarly to (3) we have

$$\left(\frac{\partial^2 \underset{21}{H^a}}{\partial 't^1 \partial 't^2}\right)_{\substack{'t^1=t^1 \\ 't^2=t^2}} = -\underset{21}{R^a} = \underset{12}{R^a} \tag{8}$$

It follows from (3) that neglecting the terms of the third order with respect to the increments $\Delta t^1 = 't^1 - t^1$, $\Delta t^2 = 't^2 - t^2$, we can represent (2) thus:

$$'u^a \approx u^a - \frac{1}{2}\ \underset{12}{R^a}(u^c,\ t^1,\ t^2)\ \Delta t^1 \Delta t^2 \tag{9}$$

Let $\overset{(a)}{\Omega^i}(u^c,\ t^1,\ t^2)$ $(i=1,\ \ldots,\ N)$ be a field of a local geometric object of the class r defined on the surface (1). Upon the transformations of coordinates in the local X_m's

$$u^{a'} = \delta^{a'}_{a}\,\varphi^{a}(\xi^{a},\ u^{c}) \tag{10}$$

the components of this geometric object transform according to the equations:

$$\overset{(a')}{\Omega^i} = F^i\left\{\overset{(a)}{\Omega^j},\ u^a,\ \varphi^a(\xi^\lambda(t^1,\ t^2),\ u^c),\ \varphi^a_{b_1\ldots b_h}(\xi^\lambda(t^1,\ t^2),\ u^c)\right\}\ (h=1,\ \ldots,\ r) \tag{11}$$

where $\varphi^a_{b_1\ldots b_h}$ are the partial derivatives of φ^a.

As a result of the point transformation (2) in the local $X_m(M_0)$ we obtain from the geometric object $\overset{(a)}{\Omega^i}$ a new geometric object $\underset{12}{\overset{(a)}{*\Omega^i}}$ of the same kind:

$$\underset{12}{\overset{(a)}{*\Omega^i}} = F^i\left\{\overset{(a)}{\Omega^j}\left(\underset{21}{H^c}(u^c,\ t^1,\ t^2,\ 't^1,\ 't^2),\ t^1,\ t^2\right);\ \underset{21}{H^a}(u^c,\ t^1,\ t^2,\ 't^1,\ 't^2),\ u^a;\right.$$
$$\left.\underset{12}{H^a_{b_1\ldots b_h}}\left(\underset{21}{H^c}(u^c,\ t^1,\ t^2,\ 't^1,\ 't^2)\ t^1,\ t^2,\ 't^1,\ 't^2\right)\right\} \tag{12}$$

where $\underset{12}{H^a_{b_1\ldots b_h}}$ are the partial derivatives of H^a.

Considering t^1, t^2 as fixed and $'t^1$, $'t^2$ as variable we obtain a two-parameter set of the geometric object $\underset{12}{\overset{(a)}{*\Omega^i}}$ in the local $X_m(M_0)$. The values of the partial derivatives of the first order of $\underset{12}{\overset{(a)}{*\Omega^i}}$ with respect to the variables $'t^1$, $'t^2$ for $'t^1 = t^1$, $'t^2 = t^2$ are equal to zero. Similarly, of the partial derivatives of the second order only the values of the mixed derivative can be different from zero. Denoting

$$\underset{12}{\overset{H\,(a)}{D}}\,\overset{(a)}{\Omega^i} = -\left(\frac{\partial^2\,\underset{12}{\overset{(a)}{*\Omega^i}}}{\partial 't^1 \partial 't^2}\right)_{\substack{'t^1=t^1 \\ 't^2=t^2}} \tag{13}$$

we obtain by means of (3) and (8)

$$\underset{12}{\overset{H\,(a)}{D}}\,\overset{(a)}{\Omega^i} = -\underset{12}{R^b}\left(\frac{\partial \overset{(a)}{\Omega^i}}{\partial u^b} + \underset{0}{F^i_b}\right) + \sum_{h=1}^{r} \underset{0}{F^i_{\varphi^a_{b_1\ldots b_h}}}\ \underset{12}{R^a_{b_1\ldots b_h}} \tag{14}$$

where $\underset{0}{F^i_b}$, $\underset{0}{F^i_{\varphi^a_{b_1\ldots b_h}}}$ are the values of the partial derivatives of F^i for $\varphi^a = u^a$, and $\underset{12}{R^a_{b_1\ldots b_h}}$ are the partial derivatives of R^a. It is easily seen that $\frac{1}{2}\underset{12}{\overset{H\,(a)}{D}}\,\overset{(a)}{\Omega^i}\Delta t^1 \Delta t^2$ coincides with Lie's differential ([2], p. 140—142) of the geometric object $\overset{(a)}{\Omega^i}$ corresponding to the infinitesimal point transformation (9) of the group of holonomicity.

Upon the transformations of coordinates (10) $\overset{H}{D}_{12}\overset{(a)}{\Omega^i}$ undergo the following transformations:

$$\overset{H}{D}_{12}\overset{(a')}{\Omega^i} = F^i_{\cdot j}\left\{\overset{(a)}{\Omega^j},\ u^a,\ \varphi^a(\xi^\lambda(t^1,\ t^2),\ u^c),\ \varphi^a_{b_1..b_h}(\xi^\lambda(t^1,\ t^2),\ u^c)\right\}\overset{H}{D}_{12}\overset{(a)}{\Omega^j} \tag{15}$$

It follows that $\overset{H}{D}_{12}\overset{(a)}{\Omega^i}$ determine a geometric object only in the case where $F^i_{\cdot j}$ are linear functions of $\overset{(a)}{\Omega^i}$. But $\overset{H}{D}_{12}\overset{(a)}{\Omega^i}$ together with $\overset{(a)}{\Omega^i}$ always determine a geometric object.

Suppose now that the connexion is linear, then we have

$$\overset{H}{D}_{12}\overset{(a)}{\Omega^i} = \overset{H}{D}_{\alpha\beta}\overset{(a)}{\Omega^i}\,\xi^{(1)\alpha}_{1}\,\xi^{(1)\beta}_{2} \tag{16}$$

where

$$\overset{H}{D}_{\alpha\beta}\overset{(a)}{\Omega^i} = -R^{\cdot\cdot b}_{\cdot\alpha\beta}\left(\frac{\partial\overset{(a)}{\Omega^i}}{\partial u^b} + F^i_{\cdot 0\,b}\right) + \sum_{h=1}^{r} F^i_{\cdot 0\,\varphi^a_{b_1..b_h}}\,R^{\cdot\cdot a}_{\cdot\alpha\beta\,b_1..b_h} \tag{17}$$

Let $D_{t2}\overset{(a)}{\Omega^i}$ be the absolute derivative of $\overset{(a)}{\Omega^i}$ along the coordinate lines $t^1 = \text{const}$. $\overset{(a)}{\Omega^i}$, $D_{t2}\overset{(a)}{\Omega^i}$ is a field of local geometric object defined on the surface (1). Considering its absolute derivative along the coordinate lines $t^2 = \text{const}$, we obtain the object $D_{t1}D_{t2}\overset{(a)}{\Omega^i}$ called the mixed absolute derivative of the second order. Similarly we define the mixed derivative $D_{t2}D_{t1}\overset{(a)}{\Omega^i}$.

It can be proved that there holds a generalized Ricci's identity

$$D_{t1}D_{t2}\overset{(a)}{\Omega^i} - D_{t2}D_{t1}\overset{(a)}{\Omega^i} = \overset{H}{D}_{12}\overset{(a)}{\Omega^i} \tag{18}$$

Let now

$$\xi^\alpha = \xi^\alpha(t^1,\ t^2,\ t^3) \tag{19}$$

be the equations of a three-dimensional surface in the base X_n. Denote by $\overset{a}{R}_{12}$, $\overset{a}{R}_{23}$, $\overset{a}{R}_{31}$ the quantities analogous to (4) which correspond to the two-dimensional surfaces $t^3 = \text{const}$, $t^1 = \text{const}$, $t^2 = \text{const}$, and by D_{t1}, D_{t2}, D_{t3} the symbols of the absolute derivatives along the coordinate lines of the surface (19).

Consider the eight points $M_0(t^1, t^2, t^3)$, $M_1('t^1, t^2, t^3)$, $M_2(t^1, 't^2, t^3)$, $M_3(t^1, t^2, 't^3)$, $M_{12}('t^1, 't^2, t^3)$, $M_{23}(t^1, 't^2, 't^3)$, $M_{13}('t^1, t^2, 't^3)$, $M_{123}('t^1, 't^2, 't^3)$. Let

$$'u^a = \underset{123}{H^a}(u^c,\ t^1,\ t^2,\ t^3,\ 't^1,\ 't^2,\ 't^3) \tag{20}$$

be the transformation of the group of holonomicity corresponding to the representations of the local X_m's along the way $M_0M_1M_{12}M_{123}M_{13}M_1M_0M_3M_{23}M_2M_0M_2M_{23}M_{123}M_{12}M_2M_0M_1M_{13}M_3M_0M_3M_{13}M_{123}M_{23}M_3M_0M_2M_{12}M_1M_0$.

It can be shown that

$$\left(\frac{\partial^3 \underset{123}{H^a}}{\partial' t^1 \partial' t^2 \partial' t^3}\right)_{t^i = t'} = -D_{t1}\overset{a}{R}_{23} - D_{t2}\overset{a}{R}_{31} - D_{t3}\overset{a}{R}_{12} = 0 \tag{21}$$

This gives a generalization of Bianchi's identity ([2], p. 132—134) and its geometrical interpretation for the connexion in the compound manifold.

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MATHEMATICS

ON A PROBLEM OF EXTRAPOLATION OF A. N. KOLMOGOROFF

By M. KREIN

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Let $\sigma(\lambda)=\sigma(\lambda-0)$ $(-\infty<\lambda<\infty,\ \sigma(-\infty)=0)$ be a certain bounded non-decreasing function, and L_σ, the Hilbert space of all σ-measurable and σ-integrable together with their squares functions $\varphi(\lambda)$ $(-\infty<\lambda<\infty)$ with the usual definition of the scalar product:

$$(\varphi, \psi)_\sigma = \int_{-\infty}^{\infty} \varphi(\lambda)\overline{\psi(\lambda)}\, d\sigma(\lambda) \quad (\varphi, \psi \in L_\sigma)$$

By $L_\sigma(E)$, where E is a certain set of real numbers t, we denote the linear closed envelope in L_σ of all elements $\exp(it\lambda) \in L_\sigma$, where $t \in E$.

A. Kolmogoroff proposed * the following general problem from the theory of statinary random functions, which may be formulated in analytical form as follows:

(K) *Two sets E_1 and E_2 of real numbers are given. To find the conditions which must be satisfied by a non-decreasing bounded function $\sigma(\lambda)=\sigma(\lambda-0)$ $(-\infty<\lambda<\infty)$ in order that $L_\sigma(E_1)=L_\sigma(E_2)$.*

In the case when E_1 is the sequence of all integers (positive and negative) less than a given one, and E_2 is the sequence of all integers, as well as in the case when E_1 consists of a finite number of consecutive integers, and E_2 is the sequence of all other integers, the problem (K) was solved by A. Kolmogoroff in 1939 [1] (a detailed solution is to be found in [2,3]) **.

In the same year, solving the problem of prolongation of Hermite-positive functions, the author obtained accidentally (quite unconnected with the investigations of A. Kolmogoroff) the solution of the problem (K)in the case, where E_1 is a finite interval and E_2, the whole infinite real axis, but for want of space [4] omitted to formulate the result. At present the solution of the problem (K) in this case (and a somewhat more general problem) is stated by the author at the end of his note [5] on the problem of continuation of helics in the Hilbert space.

A. Kolmogoroff drew the attention of the author to the special interest, which the problem (K) represents in the case where E_1 is a half-axis, and E_2 $(\supset E_1)$, the whole axis.

In the present note we indicate the solution of the problem (K) in this case ***, which is obtained as a corollary of the solution of a more general question (cf. Theorem 1 and its corollary).

* In a letter to the author.

** In the second case A. Kolmogoroff published the solution under the condition that E_1 consists only of one integer [3, 2].

*** Without reducing the generality we may assume that E_1 is the positive half-axis $t \geqslant 0$.

1. Denote by H_ζ the class of functions $\varphi(\zeta)$ $(I\zeta > 0)$ holomorphic in the upper half-plane, such that $|\varphi(\zeta)|^2$ possesses in this half-plane a harmonical majorant. A holomorphic function $\varphi(\zeta)$ $(I\zeta > 0)$ belongs to the class H_ζ if and only if the function

$$f(z) = \varphi(\zeta), \quad \text{where} \quad \zeta = i\frac{1-z}{1+z}, \quad z = \frac{i-\zeta}{i+\zeta} \; (|z| < 1)$$

belongs to the class H_z, where by H_z is denoted the class of all holomorphic functions $f(z)$ $(|z| < 1)$ such that

$$f(z) = c_0 + c_1 z + c_2 z^2 + \ldots, \quad \text{where} \quad \sum_{k=0}^{\infty} |c_k|^2 < \infty$$

Another necessary and sufficient condition for the function $\varphi(\zeta)$ to belong to H_ζ consists in that $(\zeta+i)^{-1}\varphi(\zeta) \in \mathfrak{H}_\zeta$ *, where $\mathfrak{H}_\zeta$ denotes the class of all holomorphic functions $\psi(\zeta)$ $(I\zeta > 0)$ such that

$$\int_{-\infty}^{\infty} |\psi(\lambda + i\mu)|^2 \, d\lambda < M_\psi < \infty, \; \mu > 0$$

Every function $\varphi(\zeta) \in \mathfrak{H}_\zeta$ possesses almost everywhere on the real axis limit values $\varphi(\lambda)$, to which it tends on all non-tangent paths. The same relates, of course, also to the functions $\psi(\zeta) \in \mathfrak{H}_\zeta$.

By H_λ (correspondingly, H_θ and $\mathfrak{H}_\lambda$) we denote the set of all boundary functions for the functions $\varphi(\zeta) \in H_\zeta$ (correspondingly, $f(z) \in H_z$ and $\psi(\zeta) \in \mathfrak{H}_\zeta$).

In the sequel L_λ denotes a certain linear set of functions from L_σ, possessing the following properties:

1) $1 \in L_\lambda$,

2) if $\varphi(\lambda) \in L_\lambda$, then $\exp(it\lambda)\varphi(\lambda) \in L_\lambda$ for $t \geqslant 0$.

Theorem 1. *The set $L_\lambda \subset L_\sigma$ is not dense in L_σ if and only if the following two conditions are satisfied:*

a) $$-\infty < \int_{-\infty}^{\infty} \frac{\log \sigma'(\lambda)}{1+\lambda^2} \, d\lambda \; (< \infty), \tag{1}$$

b) *there exists a function* $\Gamma(\lambda) \in H_\lambda$ *such that* $\int_{-\infty}^{\infty} \frac{|\Gamma(\lambda)|^2}{\sigma'(\lambda)} \frac{d\lambda}{1+\lambda^2} < \infty$ *and* $\Gamma(\lambda)\varphi(\lambda) \in H_\lambda$ *for any* $\varphi \in L_\lambda$.

Proof. Denote by $\overline{L}_\lambda$ the closure of L_λ in L_σ. In virtue of 2), if $\varphi \in L_\lambda$, then also $\exp(it\lambda)\varphi(\lambda) \in \overline{L}_\lambda$ for $t \geqslant 0$. And since every function $p(\lambda)$ $(-\infty < \lambda < \infty)$ of the form

$$p(\lambda) = c + \int_{-\infty}^{\infty} \exp(it\lambda) q(t) \, dt, \quad \text{where} \quad \int_{-\infty}^{\infty} |q(t)| \, dt < \infty \tag{2}$$

is the limit of a certain uniformly convergent in every finite interval and uniformly bounded sequence of trigonometrical polynomials $P_n(\lambda)$ $(n = 1, 2, \ldots)$ of the form

$$P_n(\lambda) = \sum a_k^{(n)} \exp(it_k^{(n)}\lambda) \qquad (t_k^{(n)} \geqslant 0),$$

we must have that together with $\varphi \in \overline{L}_\lambda$ also $p(\lambda)\varphi(\lambda) \in \overline{L}_\lambda$.

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* This fact may be, for instance, deduced from Theorems VII, IX of the paper of Kryloff (*).

In particular, putting in (2) $c=-1$, $q(t)=\exp(-t)$ $(-\infty<t<\infty)$, we find $p(\lambda)=\frac{i-\lambda}{i+\lambda}$ and, consequently,

$$\frac{i-\lambda}{i+\lambda}\varphi(\lambda)\in L_\lambda, \quad \text{if} \quad \varphi(\lambda)\in\overline{L}_\lambda \tag{3}$$

Put

$$\tau(\theta)=\sigma\left(\operatorname{tg}\frac{\theta}{2}\right) \qquad (-\pi\leqslant\theta\leqslant\pi) \tag{4}$$

and consider the Hilbert space L_τ of all τ-measurable and τ-integrable together with their squares functions $g(\theta)$ $(-\pi\leqslant\theta\leqslant\pi)$. Evidently, the transformation

$$g(\theta)=\varphi(\lambda), \quad \lambda=\operatorname{tg}\frac{\theta}{2}=\frac{1}{i}\,\frac{e^{i\theta}-1}{e^{i\theta}+1}$$

establishes a linear isometrical correspondence T $(g=T\varphi)$ between L_σ and L_τ.

Let $L_\theta=TL_\lambda$, and consequently $\overline{L}_\theta=T\overline{L}_\lambda$ ($\overline{L}_\theta$ being the closure of L_θ in L_τ). In virtue of the properties 1) and 3) of the aggregate L_λ $1\in L_\theta$ and, if $g\in L_\theta$, then $\exp(i\theta)\,g(\theta)\in L_\theta$. Consequently, by Theorem 1 of our note [7] L_θ is not dense in L_τ if and only if

α) $-\infty<\int\limits_{-\pi}^{\pi}\log\tau'(\theta)\,d\theta$

β) there exists a function $G(\theta)\in H_\theta$ such that

$$\int\limits_{-\pi}^{\pi}\frac{|G(\theta)|^2}{\tau'(\theta)}\,d\theta<\infty$$

and $G(\theta)\,g(\theta)\in H_\theta$ for any $g(\theta)\in L_\lambda$.

But if $L_\theta\neq L_\tau$, then $\overline{L}_\lambda\neq L_\sigma$, and conversely; on the other hand, in view of (4), the condition a) is equivalent to the condition α), and the condition β), to the condition b), if we observe the transformation $G(\theta)=\Gamma(\lambda)$ $(\lambda=\operatorname{tg}\theta/2)$, the transformation (4) and what has been stated above on the classes H_θ and H_λ.

The theorem is proved.

Corollary. In order that the linear envelope L_λ^+ of the set of functions $\exp(it\lambda)\in L_\sigma$ $(t\geqslant 0)$ should not be dense in L_σ, it is necessary and sufficient that the function $\sigma(\lambda)$ should satisfy the condition (1).

2. If the conditions a) and b) of Theorem 1, or, which is the same thing, the conditions α) and β), are satisfied, we may assert in view of Theorem 2 [8] that there exists a convergent Blashke product

$$B(z)=z^p\prod\frac{a_k-z}{1-\bar{a}_kz}\cdot\frac{|a_k|}{a_k} \qquad (p\geqslant 0,\ 0<|a_k|<1,\ k=1,2,\ldots)$$

such that the values of every function $B(e^{i\theta})f(e^{i\theta})$ $(f(e^{i\theta})\in L_\theta)$ coincide almost everywhere with the limit values of a certain meromorphic function in the unit circle of a bounded type. Moreover, if $B(z)$ is chosen in such a way that it possesses no «superfluous» zeroes, and if we put

$$F_\tau(z)=\sqrt{2\pi}\,B(z)\exp\left\{\frac{1}{4\pi}\int\limits_{-\pi}^{\pi}\frac{e^{i\theta}+z}{e^{i\theta}-z}\log\tau'(\theta)\,d\theta\right\} \tag{5}$$

then the function $F_\tau(z)$ will possess the following properties:

I′. $F_\tau(z)\in H_2$, $F_\tau(e^{i\theta})f(e^{i\theta})\in H_\theta$ for any $f(e^{i\theta})\in L_\theta$.

II′. $\tau'(\theta)=\frac{1}{2\pi}|F(e^{i\theta})|^2$ (almost everywhere).

III′. If we put $\Phi_z(e^{i\theta}) = F^{-1}(e^{i\theta})$ at the points θ, where $F_z(e^{i\theta}) \neq 0$ and where there exists a finite derivative $\sigma'(\theta)$, and put $\Phi_z(e^{i\theta}) = 0$ at all the remaining points, then $\Phi_z(e^{i\theta}) \in \overline{L_\theta}$.

Putting $\sqrt{2}\, F_z(z) = (\zeta + i)\, D(\zeta)$, $B(z) = b(\zeta)$, $z = \frac{i-\zeta}{i+\zeta}$ $(I_z > 0)$, we obtain from (4) and (5)

$$D(\zeta) = \sqrt{2\pi}\, b(\zeta) \exp\left\{ \frac{1}{4\pi i} \int_{-\infty}^{\infty} \frac{1 + \lambda\zeta}{\lambda - \zeta} \frac{\log \sigma'(\lambda)}{1 + \lambda^2}\, d\lambda \right\} \tag{6}$$

In virtue of I′—III′ we shall have:

I. $D(\zeta) \in H_\zeta$, $D(\lambda)\varphi(\lambda) \in H_\lambda$ for any $\varphi(\lambda) \in \overline{L_\lambda}$.

II. $\sigma'(\lambda) = \frac{1}{2\pi} |D(\lambda)|^2$ (almost everywhere).

III. If we put $Q(\lambda) = (i + \lambda)^{-1} D^{-1}(\lambda)$ for those λ for which $D^{-1}(\lambda) \neq 0$ and for which there is a finite derivative $\sigma'(\lambda)$, and put $Q(\lambda) = 0$ for the rest of λ, then $Q(\lambda) \in \overline{L_\lambda}$.

Since $D(\zeta) \in H_\zeta$ (cf. (8)),

$$D(\zeta) = \int_0^\infty \exp(i\zeta t)\, \gamma(t)\, dt, \quad D(\lambda) = \lim_{A \to \infty} \int_{-A}^{A} \exp(it\lambda)\, \gamma(t)\, dt$$

where

$$\gamma(t) = \lim_{A \to \infty} \frac{1}{2\pi} \int_{-A}^{A} \exp(-i\lambda t)\, \gamma(t)\, dt, \quad \int_{-\infty}^{\infty} |\gamma(t)|^2\, dt = \frac{1}{2\pi} \int_{-\infty}^{\infty} |D(\lambda)|^2\, d\lambda.$$

Theorem 2 *. *The distance* $d(s)$ $(s > 0)$ *of the element* $\exp(is\lambda)$ *from* L *in the metrics of the space* L_2 *is given by the formula*

$$d(s) = \int_0^s |\gamma(t)|^2\, dt \qquad (s > 0)$$

For want of space we omit the proof of Theorem 2.

Remark. From the construction of $B(z)$ and $b(\zeta)$ follows that if L_λ is L_λ^+, *i. e.* the linear envelope of the elements $\exp(it\lambda)$ $(t \geqslant 0)$, then in (6) we have to put $b(s) \equiv 1$. In this case, as may be easily seen, $d(s) > 0$ for all $s > 0$.

The results obtained by us may be interpreted as certain propositions relating to the problem of continuation of semi-infinite unitary lines ξ_t $(-\infty < t < a)$ (cf. (7)). These propositions may be generalized to the case of semi-infinite helical arcs.

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* Cp. Theorem 2 of A. Kolmogoroff's note (3).

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MATHEMATICAL PHYSICS

DIFFRACTION OF RADIO-WAVES AROUND THE GLOBE*

By W. A. FOCK, Member of the Academy

This paper contains a theoretical discussion of the problem of propagation of radio-waves around a homogeneous Earth surface. Diffraction effects are considered, whereas the influence of the ionosphere is neglected. A more detailed account is to appear as a separate monograph, the present paper being a brief summary of the results obtained.

1. Let r, ϑ, φ denote spherical coordinates having their origin at the centre of the globe. The equation of the Earth surface is $r=a$, where a is the radius of the globe. At point $r=b$, $\vartheta=0$ $(b>a)$ a vertical electric dipole is supposed to be present. As well known, the field may be expressed by the Hertz's function U (the vertical component of Hertz's vector), satisfying the equation $\Delta U+k^2U=0$. The value of the field at the Earth surface is expressible in term of the quantities

$$U_a=(U)_{r=a}; \qquad U_a'=\left(\frac{\partial}{\partial r}(rU)\right)_{r=a} \tag{1}$$

These quantities are known to be developable into series. Put

$$k=2\pi/\lambda; \quad k_2=k\sqrt{\eta}; \quad \eta=\varepsilon+i4\pi\sigma/ck \tag{2}$$

where λ is the wave-length in vacuum, and η is the complex dielectric constant of the Earth. Let us introduce the functions

$$\zeta_n(\rho)=\sqrt{\frac{\pi\rho}{2}}H^{(1)}_{n+1/2}(\rho); \qquad \psi_n(\rho)=\sqrt{\frac{\pi\rho}{2}}J_{n+1/2}(\rho)$$
$$\gamma_n(\rho)=\psi_n'(\rho)/\psi_n(\rho) \tag{3}$$

where $H^{(1)}_{n+1/2}(\rho)$ and $J_{n+1/2}(\rho)$ are Hankel's and Bessel's functions, respectively. Then the quantity U_a can be represented as a series in Legendre polynomials $P_n(\cos\vartheta)$, namely

$$U_a=-\frac{1}{kab}\sum_{n=0}^{\infty}\frac{(2n+1)\,\zeta_n(kb)}{\zeta_n'(ka)-\frac{k}{k_2}\gamma_n(k_2a)\,\zeta_n(ka)}P_n(\cos\vartheta) \tag{4}$$

The quantity U_a' is representable in the form of a similar series.

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* Reported at the Physical Institute of the Academy on May 30, 1944, and to a conference of the Physico-Mathematical Section of the Academy, on December 21, 1944.

2. Expression (4) for U_a (and also the expression for U_a') is known. Our problem consists in an approximate summation of these series. The series under consideration are of the form

$$S = \sum_{\nu = 1/2,\ 3/2,\ \ldots} \nu \varphi(\nu)\, P_{\nu - 1/2}(\cos\vartheta) \tag{5}$$

where the value of $\varphi(\nu)$ is obtained by comparing (4) and (5) (in the case of the series for U_a). A straightforward summation of these series is impracticable because of the enormous number of the terms that must be taken into account. (This number is of order ka, the latter quantity being equal to the number of waves that, if placed side by side, will fill the circumference of the globe). So we have first to transform the series into integrals, and then to compute the latter by approximate methods.

Put

$$G_\nu = \frac{\Gamma\left(\nu + \frac{1}{2}\right)\Gamma\left(\frac{1}{2}\right)}{\Gamma(\nu+1)} F\left(\frac{1}{2},\ \frac{1}{2},\ \nu+1,\ \frac{ie^{-i\vartheta}}{2\sin\vartheta}\right) \tag{6}$$

and denote by $P^*_{\nu-1/2}$ and G^*_ν the expressions obtained from $P_{\nu-1/2}(\cos\vartheta)$ and G_ν, respectively, by substituting $\pi - \vartheta$ for ϑ. We shall then have

$$P_{\nu-1/2} = \frac{1}{\pi\sqrt{2\sin\vartheta}}\left[e^{i\nu\vartheta - i\frac{\pi}{4}} G^*_\nu + e^{-i\nu\vartheta + i\frac{\pi}{4}} G_\nu\right] \tag{7}$$

and a corresponding expression for $P^*_{\nu-1/2}$. Series (5) can be written as a sum of residues of the integral

$$S = \frac{i}{2}\int \nu\varphi(\nu)\sec\nu\pi P^*_{\nu-1/2}\, d\nu \tag{8}$$

relating to the poles $\nu = \frac{1}{2},\ \frac{3}{2},\ \frac{5}{2},\ \ldots$ of the function under the integral sign. The integral (8) can be represented as a sum of three integrals

$$S = S_1 + S_2 + S_3 \tag{9}$$

where

$$S_1 = \frac{e^{-i\frac{\pi}{4}}}{\pi\sqrt{2\sin\vartheta}} \int_{C_1} \nu\varphi(\nu) e^{i\nu\vartheta} G^*_\nu\, d\nu \tag{10}$$

$$S_2 = -\frac{1}{2}\int_{C_2} \nu\varphi(\nu)\sec\nu\pi e^{i\nu\pi} P_{\nu-1/2}\, d\nu \tag{11}$$

$$S_3 = \frac{i}{2}\int_{C_3} \nu\varphi(\nu)\sec\nu\pi\, P^*_{\nu-1/2}\, d\nu \tag{12}$$

The contour C_1 encloses the poles of $\varphi(\nu)$ (lying in the first quadrant). The contour C_2 also encloses these poles and leaves the poles of $\sec\nu\pi$ outside. The contour C_3 is a straight line running downwards within the second and fourth quadrant and crossing the origin. An estimate of the integrals S_2 and S_3 shows that they are both small in comparison with S_1, the integral S_2 being a magnitude of the same order as the amplitude of the wave that has travelled, by virtue of diffraction alone, around the globe, and the integral S_3 being of the same order as the amplitude of the wave that has traversed the globe while subject to the absorption taking place within the Earth. It will be obvious that the error committed by putting the sum S equal to the integral S_1 is negligible as compared with the errors arising from the idealization of our physical problem.

3. The position of the relevant part of the integration contour in the integral S_1 varies with the point for which that integral is calculated. If γ denotes the angle between the vertical at the point of observation and the direction to the source (dipole), then we have a characteristic parameter in the quantity

$$p = (ka/2)^{1/3} \cos\gamma. \tag{13}$$

Large positive values of p correspond to the illuminated region. Values of the order of unity (positive as well as negative) correspond to the penumbral region. And large negative values belong to the dark region.

In the case of large positive values of p within the relevant range of integration, Debye's expressions can be applied to the Hankel functions entering into $\varphi(v)$. Making use of them and employing the stationary phase method it is possible to show that if the condition

$$kh\cos\gamma \gg 1 \tag{14}$$

is satisfied ($h = b - a$ being the elevation of the source above the Earth), the so-called «reflection formula» is obtained for the Hertz function. This formula may be written

$$U_a = \frac{e^{ikR}}{R} W; \quad W = \frac{2}{1 + \frac{k}{k_2}\sqrt{1 - \frac{k^2}{k_2^2}\sin^2\gamma}\sec\gamma} \tag{15}$$

R being the distance between the observation point and the source ($R = \sqrt{a^2 + b^2 - 2ab\cos\vartheta}$). If we replace condition (14) by the inequalities

$$\left.\begin{aligned} 1 &\ll R^2/h^2 \ll (ka)^{2/3} \\ 1 &\ll kR \ll a/h \end{aligned}\right\} \tag{16}$$

and apply a generalized method of stationary phase, whereby allowance is made for the rapid change of the denominator in the integrand near the extremum point of the phase, we shall arrive to the well-known Weyl—van der Pohl formula which can be written in the form

$$W = 2 - 4\sigma e^{-(\sigma+\tau)^2} \int_{i\infty}^{\sigma+\tau} e^{\alpha^2}\, d\alpha \tag{17}$$

where

$$\sigma = e^{i\frac{\pi}{4}} \frac{k}{k_2}\sqrt{\frac{kR}{2}}; \quad \tau = e^{i\frac{\pi}{4}} \frac{h}{R}\sqrt{\frac{kR}{2}} \tag{18}$$

Inequalities (14) and (16) which give the conditions for the applicability of formulae (15) and (17), respectively, appear to be new, whereas the formulae themselves are well known.

4. The greatest interest attaches to the penumbral region (for which p is a magnitude of the order of unity). In this case Debye's asymptotic expressions cannot be applied in the relevant part of the integration range, and have to be replaced by the following ones

$$\zeta_{\nu-1/2}(\rho) = -i\,(\rho/2)^{1/6} w(t); \quad \zeta'_{\nu-1/2}(\rho) = i\,(\rho/2)^{-1/6} w'(t) \tag{19}$$

where $t = \frac{\nu - \rho}{(\rho/2)^{1/3}}$.

Function $w(t)$ is defined by the integral

$$w(t) = \frac{1}{\sqrt{\pi}} \int_C e^{tz - \frac{1}{3}z^3}\, dz \tag{20}$$

where the contour C is a broken line running from ∞ to 0 along the ray arc $\vartheta = -2\pi/3$, and from 0 to ∞ along the positive real axis. For finite t the error of the asymptotic expressions (19) is of the order of $\rho^{-2/3}$. Using these expressions we arrive at following formula for U_a:

$$U_a = \frac{e^{ika\vartheta}}{a\vartheta} e^{-i\frac{\pi}{4}} \sqrt{\frac{x}{\pi}} \int_\Gamma e^{ixt} \frac{w(t-y)}{w'(t) - qw(t)} dt \qquad (21)$$

where the contour Γ runs from $i\infty$ to 0 and from 0 to $+\infty$ and the values of x, y and q are

$$x = \left(\frac{ka}{2}\right)^{1/3} \vartheta; \quad y = \left(\frac{ka}{2}\right)^{-1/3} kh; \quad q = i \left(\frac{ka}{2}\right)^{1/3} \frac{\sqrt{\eta - 1}}{\eta} \qquad (22)$$

The quantity x is the reduced horizontal distance from the source, and the quantity y is the reduced height. The parameter p is expressed, in this approximation, through x and y as follows

$$p = (y - x^2)/2x \qquad (23)$$

From this it may be seen that the equation of the horizon line (the boundary of the geometrical shadow) is $x = \sqrt{y}$.

The expression (21), which constitutes our main result, is applicable in all cases (*i. e.* for all parameter values) having a practical interest. In limiting cases it yields simpler formulae. Thus, if $x \ll y \ll \frac{1}{x}$, Weyl—van der Pohl's formula is obtained, for instance. Expression (21) can also be applied to the dark region (large negative p): it is then conveniently computed as a sum of residues in the poles of the integrand, *i. e.* in the roots of the denominator $w'(t) - qw(t)$. The resulting series is essentially Watson's series, but has simpler expressions for its terms.

Formula (21) makes it also possible to investigate the penumbral region (x and y, large, p, finite). That region has never been studied before. If we put

$$V(x, y, q) = e^{-i\frac{\pi}{4}} \sqrt{\frac{x}{\pi}} \int_\Gamma e^{ixt} \frac{w(t-y)}{w'(t) - qw(t)} dt \qquad (24)$$

$$V_1(z, q) = \frac{1}{\sqrt{\pi}} \int_\Gamma \frac{e^{izt}}{w'(t) - qw(t)} dt \qquad (25)$$

then with x and y large and $x - \sqrt{y}$ finite we shall have

$$V(x, y, q) = e^{i\frac{2}{3}y^{3/2}} V_1(x - \sqrt{y}, q) \qquad (26)$$

the error involved being of the order of $\frac{1}{\sqrt{y}}$. Thus, the function V of the two arguments x, y and of the parameter q reduces to the function V_1 of a single argument $x - \sqrt{y}$ and of the same parameter. This latter function can be tabulated.

It may be remarked in conclusion that the expression (24) for V can also be obtained by the method of parabolic equation suggested by M. A. Leontovich and applied by that author to the derivation of the Weyl—van der Pohl's formula. The application of this method (in a somewhat refined form) to our problem will be discussed elsewhere.

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TECHNICAL PHYSICS

VARIATION IN THE DISPERSION OF OPTICAL GLASS AFTER THERMAL TREATMENT

By V. A. FLORINSKAYA

(Communicated by I. V. Grebenshchikov, Member of the Academy, 15. VI. 1944)

The behaviour of the refractive index of optical glass kept at constant temperatures was studied at the State Optical Institute, the work being suggested by A. A. Lebedev, Member of the Academy. 15 different temperatures were tried ranging from 82° C up to the cohesion temperature. Samples were annealed during from tens to hundreds of days. The temperature was kept constant within $\pm 0.5°$ C (1). Variations in the refractive index Δn after annealing were determined at room temperature by the interference method with an accuracy of $2 \cdot 10^{-6}$ to $3 \cdot 10^{-6}$. The kinds of the optical glass studied were the USSR makes F-1, F-2, TF-1, TF-3, TF-5, K-8, BK-10, TK-5. The samples were made of raw glass very uniform as regards its refractive index and entirely free from stress.

The results obtained are as follows.

1. At all temperatures the refractive index was found to be changing steadily until it assumed a definite value characteristic of the particular temperature.

2. Dispersion varies along with the refractive index. A definite equilibrium value of dispersion corresponds to a given temperature of annealing. This equilibrium is attained very rapidly at high temperatures, and is reached but very slowly at low temperatures.

3. The alteration of the dispersion is not the same in the flint glass as in the crown glass, but rather differs in magnitude and character being considerably greater in flint glass than in crown glass. In the case of TF-5 the maximum change in dispersion observed within a temperature range of 325—495° C was approximately $2 \cdot 10^{-4}$ for the wave-length interval 4358—6563 Å; and $1 \cdot 10^{-3}$ for the wave-length interval 3650—6563 Å.

In the case of crown glass the change in dispersion was slight. Thus, for example, in BK-10 and TK-5 at any annealing temperature including the temperatures of the critical region change in $\Delta n_g - \Delta n_c$ was from $3 \cdot 10^{-6}$ to $5 \cdot 10^{-6}$. The maximum change in dispersion observed in crown glass K-8 within the critical region for the interval 3000—6563 Å was $\sim 5 \cdot 10^{-5}$.

In flint glass the change in dispersion increases sharply with decreasing wave-length. In crown glass, within the same wave-length interval, there is a linear correlation between dispersion and wave-length. This is shown in Figs. 1 and 2. The different curves relate to different annealing temperatures. The glass varieties in question are annealed in practice at 380° and 560°, respectively.

The equilibrium lines of dispersion exhibit characteristic differences in flint glass as compared to crown glass. Figs. 3 and 4 bring out the relation between the

change in $\Delta n_g - \Delta n_c$ and the temperature. The equilibrium points are marked with crosses. In Fig. 3 different curves relate to different varieties of flint glass. In all the varieties of flint glass the equilibrium lines of dispersion run similarly, the equilibrium value of dispersion increasing with temperature. The slope of the equilibrium lines is the steeper, the heavier the variety of flint.

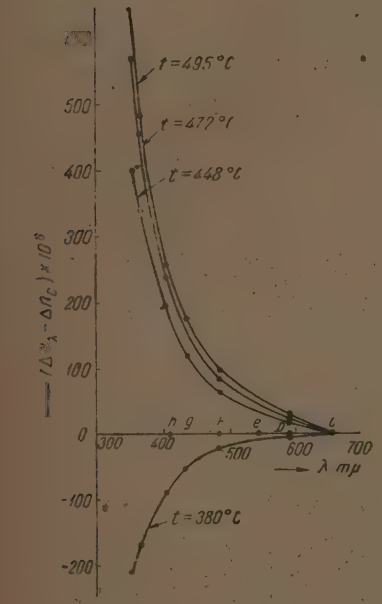

Fig. 1. Variation in the dispersion of the heavy flint TF-5 after annealing in relation to wave-length

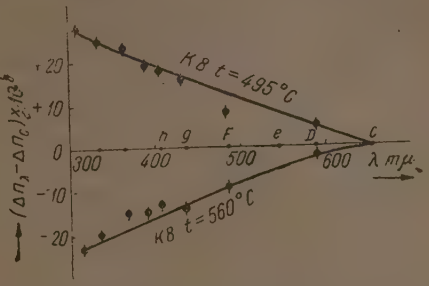

Fig. 2. Variation in the dispersion of the borosilicate crown glass K-8 after annealing as related to wave-length

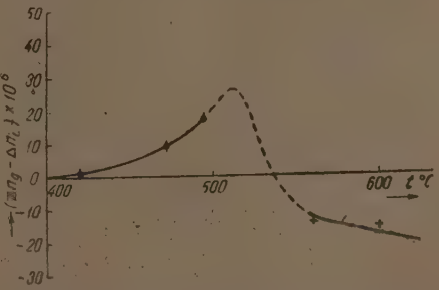

Fig. 4. Variation of dispersion in borosilicate crown glass according to annealing temperature

Dispersion grows also in crown glass K-8 (Fig. 4) within a certain temperature interval, but with a further increase of temperature the dispersion falls off. Within the interval 495—560° C there exists some extremal point. As found from calculation, the molecular refraction MR of the flint glass changes after annealing. When the dispersion of the glass increases, MR increases, too. In case there is a decrease in dispersion after annealing, there is also a decrease in MR.

The change of dispersion in flint glass was found to be attended by a change in the absorption of light in the ultra-violet region. With increase in dispersion the absorption boundary is shifted towards greater wave-lengths. And there is a shift in the opposite direction in the case of decreasing dispersion. In glass TF-5 a change in dispersion $\Delta n_{3650} - \Delta n_c$ of about $1 \cdot 10^{-3}$ causes the absorption boundary to shift 40 Å (with samples 7 mm thick). Variation in the transmission of visible light never surpassed the error of measurements.

The above facts may be interpreted to mean that the electtonic shells of certain ions suffer deformation upon thermal treatment. As 90 per cent of the total refraction in silicate glasses is due to oxygen ions, the observed alteration of optical properties in glass may be ascribed to changes in the state of oxygen ion shells.

The state of electronic shells in the oxygen ions depends on the composition of glass, and glasses containing lead are different in this respect from those with-

out lead, because the oxygen ion does not suffer the same deformation under the action of the heavy ion of Pb^{2+} as under the action of other cations, for instance, of sodium or potassium. In lead glasses the electronic shell of the oxygen ion is not as strong as in crown glass. This is shown by the greater value of the average molecular refraction of oxygen ions as compared with that in crown glass. The electronic shells of oxygen ions are therefore, *ceteris paribus*, more liable to deformation in lead glass than in crown glass. The degree of grouping of the atoms with a stable arrangement varies with temperature. The higher the temperature of annealing, the smaller the atomic complexes and the weaker their bonds.

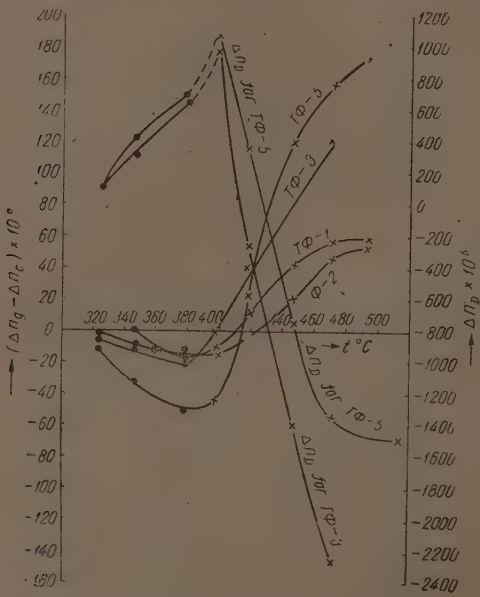

Fig. 3. Variation of dispersion in flint glass according to annealing temperature

Increase of the annealing temperature in the case of lead glass will therefore bring about a loosening of the electronic shells in the oxygen ions. On the other hand, a decrease of the annealing temperatures will strengthen the electronic shells in these ions. This is bound to change the optical properties of the glass in the direction in which they were actually found to have changed. In crown glass the deformation of electronic shells caused by rearrangements of atoms is considerably less, while the rearrangement itself may be of a more complex nature owing to the presence of numerous components; the relation of the equilibrium dispersion will be, therefore, more complex (Fig. 4).

The dispersion of the transparent bodies outside the band of absorption is determined by Lorenz-Lorentz's equation:

$$MR = \frac{n^2 - 1}{n^2 + 2} \frac{M}{d} = \sum_i \frac{C_i}{\nu_i^2 - \nu^2} \qquad (1)$$

where $C_i = \frac{1}{3\pi} \frac{e^2}{m} N p_i$. It was of interest to find out how accurately may the dispersion of the flint glass be expressed by the binomial formula (1), what are the parameters of such a formula and what kind of change

do they undergo upon annealing. It appeared that within the interval 3650 —6563 Å the dispersion of the heavy flint TF-5, which approaches in composition to a binary system, was expressed by formula (1), as accurately as up to $1 \cdot 10^{-5}$. The centre of gravity of the first absorption band lies at $\lambda = 2534$ Å; the centre of gravity of the second absorption band is at $\lambda = 1021$ Å, which is the centre of gravity of the continuous spectrum of absorption. The first band of absorption contributes to the refraction of glass 4.5 per cent, the second, 95.5 per cent, *i. e.* the dispersion of the flint glass is essentially determined by the continuous spectrum of absorption, while the first absorption band affects the transmission in the near ultra-violet. After the annealing the parameters of the formula (1) change. With the increase of the dispersion in glass TF-5 the two absorption bands are shifted toward greater wave-lengths. The shift of the first band is greater than of the second, but the change in refraction is again influenced to a greater measure by the farther band. This band is the centre of gravity of the continuous absorption spectrum of the ions of lead and oxygen. If the portion due to this absorption band in the refraction of glass is known, one can, putting the molecular refraction of the Pb^{2+} ions at 9.13 [2], determine the portion due to the continuous absorption spectrum of the ions of lead and, separately, the portion due to the continuous absorption spectrum of the ions of oxygen. In this way it is possible to determine the number of dispersion centres in a gram-molecule of oxygen ions. It was found to be equal to $3.6 \cdot 10^{31}$. Herzfeld and Wolf [3] from other data have derived a value of $3.9 \cdot 10^{31}$. The position of the centre of gravity of the continuous spectrum for Pb^{2+} ions at $\lambda = 1021$ Å appears to be plausible. This follows from a comparison with the results of other writers [4] on lighter cations and solid crystalline compounds.

Hilsch [4] and Hilsch and Pohl [5] have shown that in the crystals of NaCl. KCl, KBr contaminated with the halides of lead there always appear two bands of absorption, one of which lies in the Schuhman's region and the other in the ultra-violet. The position of the ultra-violet band is different for different halogens varying between 2500 and 3000 Å. In the pure crystalline $PbCl_2$ and $PbBr_2$ the same bands are present at the same places, *i. e.* they are caused by the presence of the ions of Pb^{2+}. Fromherz [6] has shown that when $PbCl_2$ or $PbBr_2$ are dissolved in a water solution of KCl or KBr, these characteristic absorption bands make their appearance, their position (with a definite concentration of the solution) precisely coinciding with that in crystals.

The existence of a near ultra-violet band of absorption in the flint glasses is thus confirmed by the work of the students quoted above. It follows from this that the parameters of the formula (1) which have been calculated by us from the dispersion of glass possess a real physical meaning. It is the shift of these absorption bands that is responsible for the changes in dispersion and transmission observed in flint glass upon its thermal treatment.

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CHEMISTRY

INFLUENCE OF THE CHEMICAL COMPOSITION OF URANYL GLASS UPON ITS PHOTOLUMINESCENCE

By T. I. WEINBERG

(Communicated by S. I. Wawilow, Member of the Academy, 14. VI. 1944)

The photoluminescence of crystals and solutions of uranium salts has been the subject of a considerable number of communications [1-3]. This report deals with a study of uranium glasses from the standpoint of the influence of their chemical composition, the concentration of uranium in them. impurities in the raw materials, and the conditions of melting upon the luminescence yield.

We have tried to embrace as wide a range of glasses as we could, differing as much as possible in composition and properties. We studied the influence of acid oxides, of metals of the alkali and alkaline-earth series, as well as aluminium, boron and lead upon silicate, boric and phosphoric glasses of simple composition. Since impurities in the glasses, especially iron, greatly influence their photoluminescence, most of our meltings were made with material specially purified for this purpose, and in special, pure crucibles. Uranium was added to all the glasses in the form of uranyl nitrate in quantities to make the UO_3 content in the glasses one per cent.

In order to be able to establish the influence of the factors mentioned upon the photoluminescence of uranium in the glass, the absolute luminescence yield was found by determining the ratio of the energy emitted by the uranyl glass to the total absorbed energy exciting luminescence. The radiation energy was determined from the emission spectra produced by exciting with a line of the wavelength $\lambda = 365$ mμ, derived from the spectrum of a mercury lamp. Absorbed energy was determined for the same wave-length. The yield was found by comparing the emission spectra of the uranyl glasses with those of solutions of fluorescein whose fluorescence yield is known [4] to equal 67 per cent within the concentration range of our experiments. These spectra were compared by means of a spectrophotometer. In order to get the true yield values, correction was made for reabsorption of fluorescein. From these results we plotted the spectral emission curves and found the absolute yield values for all the glasses studied.

Uranium may be contained in the glasses [5] in the form of tetravalent uranous oxide (UO_2) or hexavalent uranic oxide (UO_3). In strongly alkaline glasses the latter acts as an acid oxide, forming so-called uranates which impart an orange colour to the glass and do not give luminescence. In acid glasses, on the contrary, uranic oxide acts as a base and forms uranyl compounds which give intensive photoluminescence and impart a yellowish-green colour to the glasses. Uranous oxide gives a dark-green colouring and does not fluoresce. Usually uranium is present in glasses in several various forms at once. Glasses containing uranium in any one of these forms can be prepared only as exceptions by using special compounds. The position of the equilibrium point between the various forms of uranium must

certainly have its effect upon the photoluminescence of the glasses. In order to systematize the analysis we studied all the glasses we produced, irrespective of whether they contained uranyl or not. After this we made a study also of the conditions under which these glasses could be produced with a maximum uranyl content in order to produce glasses with considerable photoluminescence yields for practical use.

The spectral emission curves and the fluorescence yield values obtained gave quite a definite picture of influence of the chemical composition of uranyl glasses upon their photoluminescence.

Fig. 1 shows the spectral emission curves obtained for silicate and boric glasses of the $1R_2O.3SiO_2$ and $1R_2O.3B_2O_3$ type and also their fluorescence yields.

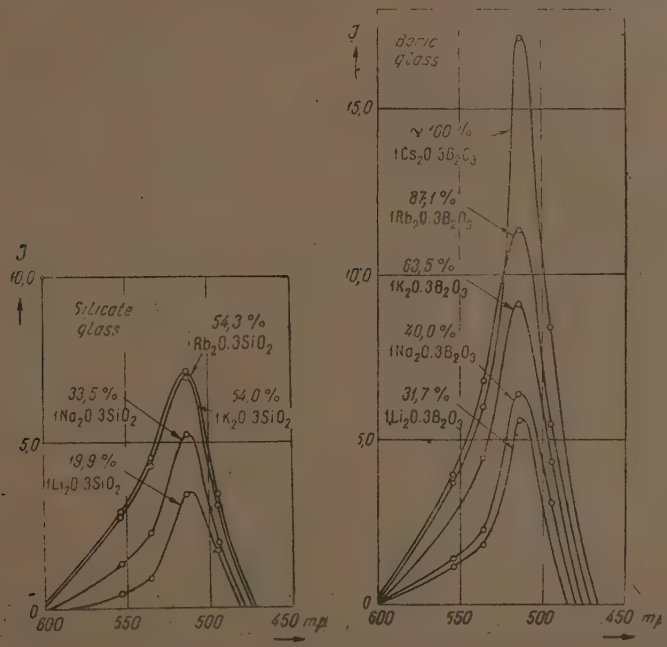

Fig. 1. The influence of alkali oxides upon the photoluminescence of silicate and boric glasses containing uranium

As this figure shows, changing the metals of the alkali group from Li to Cs gradually increases the yield in the case of both silicate and boric glasses. This is probably due to the fact that as the ionic radii of the alkali metals increase, their electric fields become weaker, decreasing their influence over the fluorescing uranyl ions. At the same time, however, the colouring of the glasses in passing from lithium to Rb and Cs glasses changes from intense yellow to a paler yellow-green. Evidently, besides their action on the fluorescing uranyl centres, alkali metal ions with large radii help to retain uranium in the uranyl form and prevent the formation of uranates.

The influence of the ratio between the alkali and acid oxides in silicate and boric glasses is shown in Fig. 2. It has been found that increasing the acidity tends to increase the fluorescence yield. This may be due to the number of uranyl centres increasing, and to the harmful action of alkali metals decreasing as the acidity of the glass rises and the alkalinity decreases. The greatest fluorescence yield, nearly 100 per cent, was given by a glass with the composition $1R_2O.9B_2O_3$. Judging by the spectral absorption of this glass, all or nearly all the uranium in it is present in the uranyl form.

Fig. 3 gives the emission curves of tricomponent glasses of the formula $1K_2O.1RO.5SiO_2$, where RO represents an oxide of one of the bivalent metals of the alkaline-earth group. In this case the curves run contrary to what may have been expected after studying the glasses of the previous series. As the ionic radius of the bivalent metal increases, the spectral emission curve, and consequently the fluorescence yield, gradually decreases. Evidently, in this case the decisive rôle is played not by the ionic radii, but by the position of the chemical equilibrium between the uranyls and uranates, which shifts appreciably towards uranate, as the atomic weight of the bivalent metal increases.

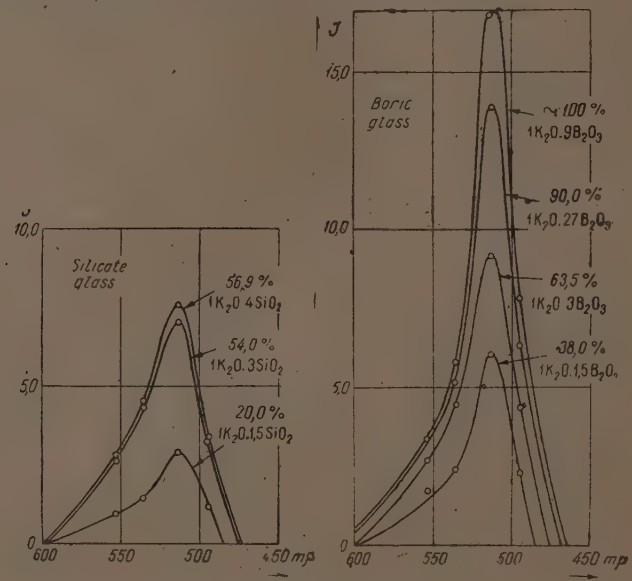

Fig. 2. The effect of acidity increase upon the luminescence of glasses containing uranium

Spectral emission curves of glasses consisting of alkaline earth and lead metaphosphates are presented in Fig. 4. It was found that glasses of this series differ pronouncedly from all other kinds. Almost all the uranium in them is present in the one, tetravalent form, which makes the fluorescence yields insignificant. Just the same, these yields increase gradually with an increase in the atomic radius of the metal. Since the concentration of uranyl ions in all these glasses is very low, the yield increase can hardly be due to a decrease in the polarizing influence of bivalent metal ions upon the uranyl ion. It is more probable that the yield increases as a result of the oxygen content in the glass increasing, since this promotes the formation of compounds in which uranium is in its highest state of oxidation. An examination of the spectral emission curves and the yields of uranyl glasses shows that the presence of several forms of uranium oxides in the glasses greatly complicates the influences of the chemical composition. Often the decisive rôle is played by the equilibria between uranyls and uranates and uranous and uranic oxides in the glass. The pronounced influence of the chemical composition does not contradict the fact that photoluminescence of uranyl glasses is due to the presence of uranyl nuclei protected from the action of the surroundings ([6]), since changes in the fluorescence yield depend largely upon the number of protected uranyl nuclei which form in the glass.

Further, on the basis of these results we made a study of the system of uranyl boric-silicate glasses in order to produce uranyl glasses with the greatest possible

fluorescence yields for practical uses. For this system we studied the influence of the uranium concentration, of ferrous impurities in the raw materials and of the conditions of melting upon the photoluminescence of uranyl glasses.

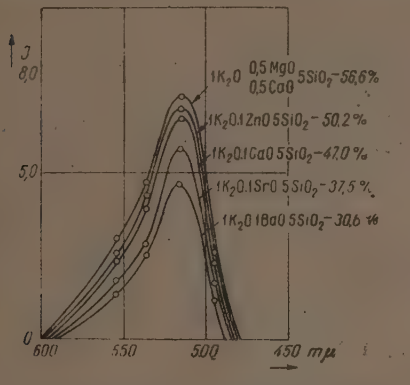

Fig. 3. The influence of alkaline-earth metal oxides upon the photoluminescence of silicate glasses

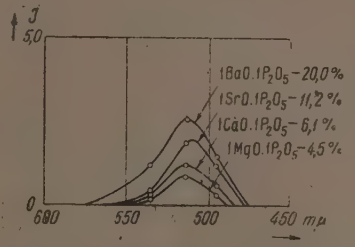

Fig. 4. The influence of alkaline-earth metal oxides upon the photoluminescence of phosphate glasses

As a result of these studies we produced under commercial conditions glasses with fluorescence yields of about 50—60 per cent of the theoretically possible yield. These glasses can already be applied for practical purposes both as luminescent screens and as efficiency promoters for gas discharge lamps, rich in ultraviolet rays.

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CHEMISTRY

CONTRIBUTION TO THE PROBLEM OF THE COMMERCIAL PRODUCTION OF MIRABILITE FROM ASTRAKHANITE

By V. I. NIKOLAEV and E. N. TVERDOVA

(Communicated by I. I. Chernjaiev, Member of the Academy, 25. V. 1944)

In a previous communication devoted to the problem of producing mirabilite from astrakhanite (1) it was established that after the astrakhanite has been dissolved in water with the addition of NaCl, the optimum conditions for converting it into mirabilite by cooling such solutions are reached when the ratio $NaCl/MgSO_4$ in solution, which may be termed the conversion coefficient, approximates 3. Such a ratio results in a practically complete conversion of the $MgSO_4$ contained in the astrakhanite into Na_2SO_4 and gives a maximum mirabilite output.

In view of the vast demand for sodium sulphate in the USSR we are now bound to face the necessity of making use, as a raw source of sulphate, of the natural mineral astrakhanite which occurs in enormous quantities in many of the salt deposits in the Soviet Union (Lake Kuuli, Jaksy-Klych, salt lakes near Astrakhan, in Middle Asia, *etc.*).

This report is to deal with the following problems:

1) The temperature at which crystallization of mirabilite from aqueous solutions of astrakhanite with admixtures of NaCl sets in.

2) The relationship between the mirabilite (accordingly, sodium sulphate) output and the concentrations of the salts in the solution.

3) Acceleration of the process of solution of astrakhanite.

1) and 2). In order to prepare a solution to meet the requirements mentioned above, astrakhanite was dissolved in water and NaCl added in quantity 2.5 times the $MgSO_4$ content in the natural astrakhanite. This solution had the following composition:

$MgSO_4$	— 6.30%	
Na_2SO_4	— 6.31%	
NaCl	— 18.47%	$\frac{NaCl}{MgSO_4} = 2,9$
Total salts	— 31.08%	

Solutions of lower concentration could be prepared from this solution by dilution, and these could be used for determining the temperature at which mirabilite crystallization sets in upon cooling to 0°C.

The results of such determinations are presented in Table 1.

Curves showing the relation between the concentration of the initial solution, the temperature at which mirabilite begins to crystallize out, and the outputs are plotted in the diagram.

Table 1 and the diagram show that a salt concentration in the brine of 24.5 per cent is enough to give yields of mirabilite and sulphate equaling those of

Table 1

Total salt concentration (% by weight)	Temperature at which crystallization of mirabilite sets in, °C	Mirabilite output in kg per m³ of solution upon cooling to 0° C	Sodium sulphate yield in kg per m³ of solution
24.23	15.1	210	92.6
25.10	16.2	256	112.8
27.88	17.2	293	129.2
30.04	—	309	136.2
31.08	17.9	317	139.5

Kara-Bogaz (about 110 kg Na_2SO_4 per m³ of solution). Raising the concentration to 30—31 per cent increases the mirabilite and sulphate outputs to a point considerably higher than those of Kara-Bogaz, *viz.* 317 kg mirabilite or 139.5 kg Na_2SO_4 per m³ of brine.

Crystallization of mirabilite under these conditions sets in at 17.9°.

The wide temperature interval within which mirabilite precipitates out of solution (from + 17.9° to 0°) suggests the possibility of harvesting mirabilite twice in a year, *e. g.* at temperature between + 17.9° and + 10° (at the beginning of autumn) and between + 10° and 0°.

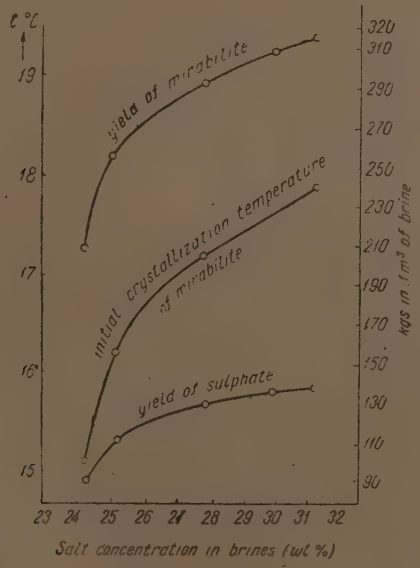

Diagram showing the relationship between the temperature at which crystallization of Glauber's salt sets in, the output of mirabilite and sulphate and the concentration of astrakhanite brines

It remains to be added only that in practice a total salt concentration of 25—28 per cent is enough to be considered satisfactory for working conditions, since such a concentration gives a greater output of mirabilite and sulphate than under the conditions of Kara-Bogaz.

3) Previous communications by V. I. Nikolaev and A. N. Kogan (2), and by V. I. Nikolaev and M. I. Preobrazhensky have pointed out the difficulties met with in dissolving astrakhanite without agitation because of the formation of a heavy solution at the bottom which diffuses upwards very slowly.

In our present study we tried bubbling air through a system of astrakhanite, NaCl and water, which resulted in the brines being agitated quite energetically and in astrakhanite passing into solution with relative rapidity.

Since astrakhanite dissolves in water congruently at temperatures above 22° C, the experiments in dissolving it with the addition of NaCl were conducted at a temperature of 25° C. 240 g of natural astrakhanite and 220 g of fine-grained NaCl were dissolved in 1 litre of water while bubbling air through the system at a rate of 2 litres per minute. In order to determine the relation between the size of the astrakhanite crystals and the rate of solution, astrakhanite was taken in one experiment in crystals from 0.8 to 1.0 cm in diameter, and in the other, in two lumps weighing 200 and 40 g, respectively (in all 240 g).

Table 2

Dimensions of crystals or weight of lumps of astrakhanite	Time of bubbling air in hours	Final concentration of salts in solution (% by weight)
0.8—1.0 cm	2	24.96
» »	4	25.68
» »	6	26.70
» »	8	27.88
200 g + 40 g	2	24.82
» »	4	25.60
» »	6	26.81
» »	8	28.01
» »	10	28.82
» »	14	30.04

The data given in Table 2 show that where air is bubbled through the system of salts and water (*i. e.* when the brines are agitated) astrakhanite dissolves just the same, irrespective of the sizes of its lumps; moreover, two hours are sufficient to give a working concentration of 24.9 per cent total salts. This phenomenon is due to the lumps of astrakhanite being usually laminated with NaCl and epsomite which dissolve easily. After these admixtures have dissolved, the large lumps of astrakhanite fall apart into small ones.

Afterwards the concentration of the solution increases much more slowly: after 8 hours it reaches 28 per cent, and only after 14 hours, 30 per cent.

Thus, the production of the required concentrations of 28—30 per cent in commercial basins should not meet with any appreciable difficulties.

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Academy of Sciences of the USSR.

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CHEMISTRY

ON A NEW METHOD OF ACETYLATION OF CELLULOSE WITH ACETYL CHLORIDE

By P. V. POPOV

(Communicated by A. E. Arbuzov, Member of the Academy, 1. VII. 1944)

There is still a great deal of uncertainty about the part played by tertiary bases, pyridine in particular, in the acetylation of cellulose with acetyl chloride.

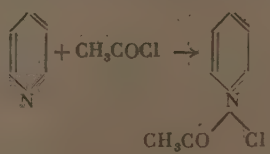
The traditional explanation (1), according to which the rôle of tertiary amines consists merely in the fixation of hydrogen chloride formed during acetylation with acyl chlorides, cannot claim to give the essentials of the process.

Investigations in which pyridine had been substituted with other tertiary bases (quinoline, dimethylaniline, *etc.*) in the acetylation of cellulose by acetyl chloride, with benzene used as solvent, other conditions being equal, showed a considerable lowering of the degree of esterification (2). The same conclusion had been drawn much earlier by other authors as well (3).

Therefore even if the fixation of hydrogen chloride evolved during esterification is of some importance when acetylation is carried out according to the above-mentioned method, still it cannot be considered a paramount factor, as Hess (4) achieved the preparation of cellulose triacetate using acetyl chloride in the absence of tertiary base, and even under the pressure of hydrogen chloride.

It may be taken for granted that the most important factor in esterification by this method is the formation of a reactive complex of pyridine with acetyl chloride (5).

The addition product of acetyl chloride and pyridine is an active transferring agent of the acetyl group, and is used as an active acetylating agent (6).



Taking all this into consideration, it seemed worthy of interest to find a substitute for pyridine capable of forming a complex with acetyl chloride, as well as fixing hydrogen chloride formed in the esterification process.

A most suitable product for this purpose seemed dioxane—a cycle ether of ethylene glycol (7).

One of the most interesting properties of dioxane, as well as of many other ethers, is its ability to take part in addition reactions, for instance, to add halogens, hydrogen halides, sulphuric acid (7), as well as acyl halides (8).

Dioxane was prepared by the method of Favorsky (7). For acetylation purified linters were used, acetyl chloride being the esterification agent.

The ratio of the reacting components was in the first experiment: 1 mole of dry linter, 6 moles of freshly distilled acetyl chloride, 20 moles of pyridine and 102 moles of pyridine used as diluent. The reaction proceeded for 8 hours, the mixture being heated on a water bath.

A detailed description of the method of esterification and of analysis may be found in literature (9).

In the second experiment instead of pyridine 122 moles of dioxane were used. Thus, dioxane replaced the 20 moles of pyridine and all the pyridine used as diluent (102 moles).

After refluxing the mixture for 8 hours the volatile products were distilled off *in vacuo*, and the esters obtained were analysed for the content of fixed acetic acid.

Results obtained (Table 1) showed that, all other conditions being equal, the degree of esterification is much higher in the presence of dioxane than of pyridine.

Table 1

Initial material	Moisture %	Acetyl chloride, moles	Substance forming the complex moles		Diluent, 102 moles	Fixed CH_3COOH %
			Pyridine	Dioxane		
Purified linter	7.0	6	20	—	Pyridine	20.0
» »	7.0	6	—	20	Dioxane	30.0

Thus, the conjecture of substituting pyridine with dioxane in this esterification reaction was confirmed. The oxonium complex of dioxane and acetyl chloride proved as active an agent for transferring the acetyl group as the ammonium complex of pyridine.

The data obtained explain the results of our previous work when acetylation was carried out with acetyl chloride in the absence of pyridine in a series of diluents (benzene, carbon tetrachloride, phenetole, nitrobenzene, *etc.*). In the case these substances are used as medium, esterification is practically very low (Table 2).

Table 2

Initial material	Moisture %	Acetyl chloride, moles	Diluent, 122 moles	Fixed CH_3COOH %
Purified linter	7.0	6	Benzene	1.8
» »	7.0	6	Carbon tetrachloride	2.9
» »	7.0	6	Phenetole	13.5
» »	7.0	6	Nitrobenzene	14.3
» »	7.0	6	Acetic acid	50.0

Acetic acid is an exception: in its presence a sharp increase in the degree of esterification is observed, this being probably connected with the formation of an active oxonium complex of acetic acid with acetyl chloride. This hypothesis is confirmed by the extensive work of Tchelintzev (10) as well as that of Shostakovsky (11).

A certain increase in the degree of esterification in such oxygen-containing media as phenetole, nitrobenzene (compared with results obtained in benzene) should be explained also by a tendency towards the formation of oxonium complexes by such substances.

Conclusions

1) It has been found that the substitution of pyridine with dioxane in the acetylation of linter with acetyl chloride leads to an increase in the degree of esterification.

2) The results obtained are a new proof of the influence of intermediate oxonium and ammonium complexes in the esterification reaction according to the method described.

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GEOLOGY

SOME NOTES ON THE VARIEGATED DEPOSITS OF THE DONETZ BASIN

By I. J. LAPKIN

(Communicated by P. I. Stepanov, Member of the Academy, 9. VI. 1944)

To the variegated deposits of the Donetz Basin belongs a diversified complex of variegated and red-coloured, mainly areno-argillaceous rocks, extensively developed both in the northern marginal parts of the Donetz Basin, and beyond these. As a rule, these sediments are united in one formation to which a Triassic age and a continental (arid) origin are assigned («the Triassic of the Donetz Basin»).

One is struck by the fact that in no place has it been possible to trace a continuous section of the Triassic of the Donetz Basin; it is very difficult therefore to correlate, according to their external features, the individual exposures of rocks variegated not as to their colour alone, but as to their lithological composition, as well. Nevertheless, even red and variegated deposits opened up by some deep holes, within the vast area of the «Great Donbass», at places situated far apart, are referred to the Triassic of the Donetz Basin.

What is then the actual state of affairs?

The first to point out the possible occurrence of the Triassic in the Donetz Basin was Barbot-de-Marni, who in one of his papers [2] wrote as follows: «After recognizing the presence of the Triassic system in our northern provinces, the question presents itself whether the Triassic exists also in the south of Russia, and whether the Bakhmut salt-bearing formation should not be subdivided into Permian and Triassic strata». In this connexion Gurov [5] observed: «Barbot-de-Marni, who was in general endeavouring to reestablish the Triassic in Russia, looked for the opportunity to separate the upper portion of the iridescent Bakhmut clays from the Permian sediments of the Bakhmut depression. He suggested that the banded marls of this depression might belong to the Triassic, but there was no evidence available supporting the separation of the latter from Permian sediments».

If the subsequent history of the discovery of the Triassic in the Donetz Basin be traced ([1, 3, 4, 8, 10, 11, 13, 14, 15] *etc.*), the conventional nature of the present meaning of this term will become clearly apparent. In the present paper the author will restrict himself to a discussion only of data furnishing a palaeontological basis for establishing the Triassic of the Donetz Basin, which is not difficult, these data being but few.

In the central part of the former Izyum region at some places (Sukhaya Kamenka, Protopivsk ravine), in the uppermost portion of the variegated beds, or, strictly speaking, in the rocks referred to these, in the so-called ironstones, shells of *Unio*-like molluscs and impressions of plants have been encountered ([14], [3]). According to the original determination by N. V. Grigoriev, the latter should be considered as a flora occurring «in the Keuper, Raethic and lower division of the Liassic; these rocks (*i. e.* rocks containing the above flora. I. L.) may, therefore, be assigned to the upper division of the Triassic or to the Lower Liassic» ([14]). Later on, Thomas confirmed the correctness of this conclusion ([16]).

It was not until recently that Lungershausen, according to his own statement, discovered in the basin of the Berek River the so-called Garazhev flora, handed

over for study to V. O. Prinada; this flora «enables us to speak of the presence of a floristic complex, apparently not younger than the Keuper».(9).

In addition, the literature contains but a single reference made by Matveyev (12) to the presence in the southern marginal part of the Donetz Basin of marine Triassic deposits. When sinking hole No. 106, near the Marievka village, this investigator discovered in variegated rocks referred to the Triassic, in the lower part «a considerable amount of *Discinia*, *Bellerophon*, and some microfauna»; and in the upper part, clays «with undetermined remains of *Orthoceras* (*Atracites*) and *Halobia*». But the specimens were lost, and the determinations of fauna were given by Matveyev without specific names according to this investigator's field notes and drill-log. That is the whole palaeontological characteristic of the Triassic of the Donetz Basin, which can hardly be considered as sufficient.

From the aforesaid it follows that the determination of the age of the variegated beds of the Donetz Basin should be revised.

The present author has shown elsewhere (7) that the «unfossiliferous» variegated rocks of the Krasny Oskol—Lissichansk anticline, developed in the lower course of the Netrius, Zherebetz and Krasnaya rivers, assigned by all the explorers of this region to the Triassic, to a considerable extent belong to Araucarian beds (containing *in situ* stems of *Dadoxylon amadokense* Zal. and other forms). It should also be noted that the «Triassic» variegated and red-coloured sediments of the Lissichansk—Kremen structure, opened up by test pits of «Uglerazvedka», which probably pass into Carboniferous deposits without any break, contain coal seams, vegetable remains of an Upper Palaeozoic appearance (this flora has not as yet been determined), and limestone bands up to 0.60 m thick (hole No. 925)*.

By analogy with the variegated rocks of the marginal part of the Donetz Basin, the deposits met with in the course of deep drilling far outside the basin (Romny, Kharkov) but of a similar external appearance, were assigned the same Triassic age. The fallibility of this view in some cases has been shown with unmistakable clearness. Thus, at Romny the «unfossiliferous» variegated rocks penetrated by drill-holes under Cretaceous or Jurassic sediments, referred to the continental Triassic of the Donetz type, do not only contain limestone bands (hole No. 8), but are also interbedded with palaeontologically characterized Carboniferous sediments (holes Nos. 6 and 7) (17). The variegated rocks met with in the course of deep drilling at the site of the Kharkov Tractor Works were found to be, according to L. I. Karyakin, of Upper Palaeozoic age (6).

It is not surprising that the Permian exposed by drilling the Gavrilov hole north of Krasnoarmeisk (Grishino) was something unexpected for the explorers who had considered the Triassic variegated beds to rest here directly upon Carboniferous sediments (15).

In addition to Palaeozoic variegated beds, at some places of the north-western marginal part of the Donetz Basin (Izyum, Sviatogorskaya) also Mesozoic variegated rocks are known, the stratigraphic position of which is established with a rather high precision, since they occur between Upper Jurassic limestones and Cenomanian glauconitic sands (3,1). In their external appearance the Upper Jurassic—Lower Cretaceous (?) variegated deposits are, as a rule, undistinguishable from the so-called Triassic ones**.

There is no doubt that the Upper Jurassic and Lower Cretaceous variegated deposits are more extensively developed than it is known at present. At some places it has been ascertained that isolated outcrops of these rocks have been described as exposures of the Triassic.

In the marginal parts of the Donetz Ridge there are apparently still younger variegated deposits. Thus, in P. I. Stepanov's opinion, the variegated rocks known on the left bank of the Donetz River, north-easth of the town of Kamensk, and

* The author has examined not only the drill-logs, but also cores from drill-holes.

** A. D. Arkhangelsky even notes that in the clayey mass of the Upper Jurassic—Lower Cretaceous (?) variegated deposits considered, there are embedded «irregular angular blocks of red clays, undistinguishable from the Triassic or Palaeozoic ones» (1).

encountered while drilling at the Razdorskaya village (stanitza) on the right bank of the Don, described as Triassic, are probably Palaeogene or partly correspond to the topmost portion of the Cretaceous (the Danian stage).

Thus, the rather scarce information so far available still enables us to establish definitely enough that the Donetz variegated deposits are of a polystage character (after P. I. Stepanov), *i. e.* of different age. As it has already been pointed out, the formation of these rocks was periodically recurring throughout a considerable length of time (Upper Palaeozoic—Mesozoic, possibly also Lower Cenozoic). It is characteristic that the formation of the variegated deposits coincides in time with definite phases of mountain-making of the Donetz Ridge, most distinctly manifest in its marginal parts. That is why it can be stated that without an interpretation of the age (and origin) of the variegated beds, chiefly of the peripheral structures of the Donetz Ridge, to establish the chronology and relation of the separate tectogenic elements to one another would be a vain attempt. The determination of the age of the Donetz variegated deposits is impeded by a poor content of organic remains. Particular attention should be paid to the elucidation of their precise stratigraphic position* and lithological composition.

It needs no arguing that a comparative lithological study of the mineral constituents of the separate variegated beds throughout the area of their development will facilitate the correlation of the sections, help to ascertain the source of the material, and also the facial and other peculiarities of the formations, as yet problematic, and which are of interest to us.

At present the origin of the Donetz variegated deposits is very obscure, since no satisfactory information is available which would help to elucidate the palaeogeography of separate epochs, to which the formation of the rocks is confined.

It should also be noted that Lutughin, speaking of the variegated deposits of the western part of the northern margin of the Donetz Basin, pointed out that «a determination of the age of the variegated bed described, which is everywhere dislocated, is of essential importance for settling the questions related to the origin of the «Donetz Ridge» (11).

At present sometimes no precise determination of the age of the rocks penetrated by drill-holes is faisible without a detailed study of the variegated and red-coloured sediments, the more so the constructing of sections of the corresponding structures. It is on the correct determination of the age and origin of the Donetz variegated deposits that depend also the results of search and prospecting, since — as it is known — a particular complex of valuable useful minerals (mineral waters, gases, *etc.*) is confined to the variegated beds. A number of other, probably no less important questions (determination of the depth of occurrence of the coal-bearing Carboniferous, age of some dislocations, *etc.*) cannot be settled without an interpretation of the variegated deposits of the Donetz Basin.

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* In some cases it is not possible to establish the position of the variegated deposits in the stratigraphical column until a revision of the age of the separate horizons is made.

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ZOOLOGY

MOSCHUS MOSCHIFERUS TUROWI SUBSP. NOV. FROM THE RUSSIAN FAR EAST

By V. ZALKIN

(Communicated by I. I. Schmalhausen, Member of the Academy, 20. IV. 1944)

The representatives of the genus *Moschus* inhabiting the Russian Far East (Amur and Ussuri provinces) have up to the present time not been studied as to their taxonomic relation to the different races of this genus. Those writers who had in some way or other contributed to the knowledge of this musk-deer did not differentiate it from the Siberian *Moschus*, considering them as a taxonomic whole.

In 1928 an interesting study concerning the taxonomy of the genus *Moschus* (1) was published by Flerow. This writer arrived at the just conclusion that the Siberian *Moschus* should be differentiated into several geographical races, more or less clearly distinguishable from one another. Speaking of the Far East *Moschus*, Flerow advanced the opinion that the latter was no separate race and that it should be referred to the subspecies *Moschus moschiferus parvipes* described by Hollister (3) from the Korea Peninsula. The representatives of this subspecies are characterized by their small general dimensions and by their very short metapodia, which is a character in common with the *Moschus* races inhabiting the southern part of the area of distribution of the genus (China, the Himalaya mountains, Eastern Tibet); alongside of some other structural characters, relative and absolute short-leggedness is just the feature characterizing the southern races of *Moschus*.

During the recent years the Zoological Museum of the Moscow University has succeeded in obtaining rather abundant collections of musk-deers from various regions of Siberia and the Far East. Among these is a fine series of skulls and flat skins kindly offered to the Museum by G. A. Salmin from the Sikhote-Alin National Park. The total of the material, along with the beautiful collections of *Moschus* available at the Zoological Museum of the Academy of Sciences of the USSR, enabled the present author to undertake a taxonomic revision of the genus *Moschus*, and at the same time to reconsider the taxonomic position of the musk-deer from the Far East.

The study of the collections, as well as the acquaintance with recent literary data on the Far East *Moschus* made it evident that the diagnosis of this form made by Flerow is lacking accuracy, and stands in need for material corrections.

Let us consider in the first place the body dimensions. If we are to compare the data on the Altai musk-deer, which go well to characterize the West Siberian *Moschus* in general, with the respective data on the Far East musk-deer, we soon become aware of the fact that the latter is but little inferior as to its body size. And what is essential, there is scarcely any difference between height at sacrum and at withers between the representatives of the two regions. This circumstance does not permit to refer the Far East musk-deer to the short-legged forms, for it

testifies to a rather considerable length of limbs and of metapodia, in particular.

	Altai ($n=6$)	Far East* ($n=30$)
Total body length	88—98	86—95
Height at withers	58—67	56—65
Height at sacrum	69—80	67—79
Ear length	8.5—10	8—11
Tail length	4—6	4—5

* Measurements by G. A. Salmin.

What made Flerow to speak of the small dimensions of Far East musk-deer were probably the small dimensions of the skull whose total length was put by him at 145 mm. As a matter of fact, the skull in this musk-deer is much larger, its size varying between 144 and 157 mm in adult animals, which comes to the same figures as in the North-Eastern Siberian musk-deer, and is but little below those for the West Siberian (148—164 mm).

Thus, the Far East musk-deer cannot be considered as an undersized and short-legged variety, and Flerow had no real reason in referring it to the subspecies *Moschus moschiferus parvipes*. Neither can it be identified with any of the subspecies reported from Siberia. The subspecies it approaches most closely is *Moschus moschiferus arcticus* Flerow, inhabiting North-Eastern Siberia, which it resembles in body and skull size, colour and many features of cranium structure. The distinction between the two subspecies consists in a longer antalveolar part of the upper jaw peculiar of the Far East musk-deer, in a shorter set of teeth and smaller size of the molars.

All that has been said above makes us consider the Far East musk-deer as a separate undescribed subspecies of the species *Moschus moschiferus* for which we suggest the name of *Moschus moschiferus turowi* and the following diagnosis:

Moschus moschiferus turowi

T y p e. Skull No. S-35510, Zoolog. Museum of the Moscow University, ♂ ad., Sikhote-Alin National Park, Terney Bay, 22.II.1935, collected by G. A. Salmin.

P a r a t y p e s. Skull No. S-34996, Zoolog. Museum of the Moscow University, ♂ ad., ibidem, 2.X.1937, coll. idem. Skull No. S-34997, Zoolog. Museum of the Moscow University, ♂ ad., ibidem, coll. idem. Skull No. S-33266, Zoolog. Museum of the Moscow University, ♂ ad., Sikhote-Alin National Park, 9.IX.1935, coll. idem. Skull No. S-33261, Zoolog. Museum of the Moscow University, ♀ ad., ibidem, 14.XII.1935, coll. idem. Skull No. 35409, Zoolog. Museum of the Moscow University, ♀ ad., ibidem, Terney Bay, 9.VIII.1937, coll. idem.

T e r r a t y p i c a. Central Sikhote-Alin.

G e o g r a p h i c a l d i s t r i b u t i o n. Amur and Ussuri provinces, probably Eastern Manchuria.

D i a g n o s i s. Differs from the West and East Siberian musk-deer in its somewhat smaller body and skull dimensions and in a brighter, more intense dark-brown coloration. Total body length up to 95 cm, height at withers up to 65 cm, at sacrum up to 79 cm. Total length of the skull in adult individuals from 144 to 157 mm. Facial part does not exceed 50 per cent to the total length of the skull. Nasal bones absolutely and relatively shorter, not above 38 per cent to the total skull length. At the brain cavity skull relatively wider. From the North-Eastern Siberian *Moschus* the subspecies under description differs in its longer antalveolar part of the upper maxilla, which makes up 32—34 per cent to the total length of the skull, and in a smaller length of the teeth set varying between 25 and 27.5 per cent to the length of the skull. True molars smaller in size. Metapodia longer.

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ENDOCRINOLOGY

GROWTH AND DIFFERENTIATION IN YOUNG *STURNUS VULGARIS* L. AS AFFECTED BY THYROIDECTOMY

By A. A. WOITKEWITSCH

(Communicated by L. A. Orbeli, Member of the Academy, 22. IV. 1944)

The regularities which underly the natural development of young in a number of praecoces have been investigated in a rather thorough manner. The hormone of the thyroid gland is found to play an important rôle in the processes of general growth and differentiation of these birds. The removal of the thyroids results in a considerable lagging of development in chicks and ducklings; the differentiation of their organisms, which among other indices can be evaluated according to the development of their plumage, suffers a strong inhibition. The expression of these phenomena in young thyroidectomized birds is the stronger, the earlier the date of operation ([1], [3], [5]). In altrices the regularities underlying the development of young have not yet been studied in sufficient detail; this may partly be accounted for by the difficulties involved in the supply of sufficiently abundant material. Out of the extensive group of altrices, development has practically been investigated in the pigeon alone ([2], [5]). The present author was the first to investigate experimentally the rôle played by the thyroid hormone in the morphogenesis of these birds. That such experiments are necessary should scarcely be emphasized, for it is only by way of experiment that it is possible to explain the sharp distinctions in the nature and intensity of morphogenetic processes in altrices and praecoces. A comparative analysis of data bearing on the normal development, and on the effect of thyroidectomy in large numbers of representatives of the two groups will make it possible to form an idea of the real relation between the determining effect of the hormonal and genetic factors upon the development processes in the various forms, and to judge of the changes this relation underwent in the process of evolution of birds.

On account of what has been stated above, I undertook in 1937 experiments with thyroidectomized altrices. When describing the technique of extirpation of thyroid glands in one of my earlier papers ([4]) I pointed out the difficulties involved in this operation practised on birds. Still more important were the difficulties in the case of young, especially at early stages of their development. The small size of the young, the loose texture of the parenchyme of the thyroid gland were not infrequently responsible for the lethal issue of the operations; and even in successful cases, regeneration of the thyroid tissue could not always be prevented.

In 1938, by courtesy of L. A. Orbeli, Member of the Academy, the author was allowed to carry out thyroidectomies of altrices at the I. P. Pavlov Biological Station, at Koltushi. The first experiments were made with young rooks and magpies. Both thyroidectomized and control birds were fed artificially and brought up in the laboratory. Part of them were put back into the nests, and fed by their parents. Only in a few birds out of the 36 young birds operated upon have I succeeded in

excising the thyroid gland completely, in which cases no regeneration of the glands took place.

In the case of a complete removal of the thyroid tissue the young rooks showed an inhibition of general growth and of differentiation of their plumage. The secondaries of the pteryliae of the dorsal and thoracal region, of neck and limbs remained deficient; if the operation was performed at an early date, they failed to develop altogether. In thyroidectomized young birds the ventral side of the body invariably bore a more scanty plumage than the dorsal one. The primaries did never fail to develop, yet their development proceeded at a lower rate than in the normal birds. Their vanes always proved shorter and narrower. The typical developmental phases in the behaviour of young birds deprived of their thyroid glands succeeded one another in an appreciably inhibited manner. The effect of thyroidectomy was more sharply expressed in young birds operated at an early developmental stage than in those operated upon at a later stage of their development (1).

It is noteworthy that the inhibition of general growth produced by thyroidectomy was found to be less clearly expressed in young rooks than in chicks and ducklings, although in both cases the operations were performed at about the same period upon hatching.

At the same laboratory I undertook, jointly with J. A. Wassiliev, experiments involving the thyroidectomy of young *Sturnus vulgaris* L. The assumptions made by us in this case were similar to those made in my experiments with young rooks. The experiments upon starlings appeared to us of particular interest, since the development in those birds proceeds at a higher rate, and their energy of growth is higher than in the rook. In the starling the development period, from the moment of hatching to the end of growth, makes up an average of 18 days. The young are born blind, naked, and but poorly differentiated. Within the very first days of life the weight of a young bird increases several times. Towards the fourth day upon hatching, dark shafts of quills are already observable under the skin of dorsal pteryliae; in the subsequent the development of these feathers proceeds very rapidly.

On account of the intensity of development processes in *Sturnus vulgaris* L., in order to bear out with maximum sharpness the effect of thyroidectomy, we had to operate at the earliest stages possible, *i. e.* not later than 2—3 days after hatching. From what has been said above it may easily be understood what difficulties are involved in operating upon so very young birds. This accounts for the fact that the experiments had to be repeatedly resumed during several years *.

During the five-year period we have operated upon a total of 113 young birds, mostly at an age of 2—3 days; out of these 64 young have survived. On many occasions the removal of the thyroid gland was no complete one, and regeneration took place. As shown by post-observational examination, complete thyroidectomy had been attained in 14 birds only.

At Koltushi we had only one completely thyroidectomized young bird (out of a total of seven birds operated upon) which was under continuous observation after his growth had been complete. Both the operated young birds and the unoperated controls were brought up in heated chambers of the laboratory. They were fed artificially, their diet being so combined as to contain all such components as the young birds would receive under natural conditions. After their growth had been complete, the young birds were transferred to voleries.

In all experiments that followed both operated young birds and controls were replaced to the same nest from which they had been taken. Both the birds under experiment and the controls were weighed at equal intervals of time, the alterations observed in their habitus described, and their growing feathers measured. By the end of the development period the birds had their wings clipped. In order

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* In 1938, at the Biological Station, Koltushi, Leningrad; in 1938, at the Biological Station near Kashira, Moscow; in 1941, at the National Park, Astrakhan; in 1941, at the Medical Institute in Kursk; and in 1943, at the Medical Institute, Alma-Ata.

to impede their movements, the birds were attached to the nest by a foot, with the aid of a silk-thread. In this way it was made possible to keep them under observation during a considerable period of time.

The most extensive material has been obtained at the Astrakhan National Park (1941, May). Out of the 62 birds operated upon 33 have survived; among these in eight birds we have succeeded in removing the thyroid glands completely. It is upon this material that are based our conclusions stated below. Experiments carried out at another date went to confirm the results obtained.

After 24 hours the effect of the operational trauma could scarcely be noticed in the status of the young birds. After three days the tissues within the field of operation were entirely healed. During the first days upon operation the thyroidectomized birds would somewhat lag behind in their total weight as compared to the controls. This difference became gradually effaced with time: in some of the nests there was no difference in weight between the experimental birds and the controls. In five cases out of 14 the weight of the thyroidectomized birds was somewhat below that of the controls throughout the period of development, but in the subsequent there was no difference at all. In our experiments on young starlings we came across a paradoxical phenomenon which does not agree with the ideas prevailing heretofore. This made us consider the results of our experiments with particular caution, and repeat the latter several times under various conditions. The results proved identical in all cases. The extirpation of the thyroid gland was accompanied with no such a high degree of inhibition of general growth as previously observed in thyroidectomized chicks and ducklings, or even in young rooks. If there was any reduction in the intensity of growth as a result of thyroidectomy, this reduction was rather negligible, and it gave us no right to speak of an inhibition in the general growth of those birds.

The autopsies of the young birds that had achieved their development showed the thyroidectomized birds to accumulate much more fat under the skin and within their body cavities. Consequently, the coincidence in the weights of experimental birds and controls was due to fat accumulation by the former. The enhanced fat infiltration compensates for the lagging behind in general growth as a result of operation. But even if allowance be made for this circumstance, the magnitude which expresses the degree of deviation from the normal rate of growth in thyroidectomized starlings will still be below the one recorded in our earlier experiments with other altrices (rooks). The latter were found to display a less pronounced inhibition of growth caused by the absence of the thyroid hormone than the praecoces.

In thyroidectomized young starlings the development of plumage assumes a different course according to the pteryliae: in those pteryliae where the feather anlages had been formed prior to the operation, the plumage developed at a lower rate than in the control. The vanes of those feathers, in particular, those of the wing and tail quills, were narrower than in the control. The feathers of those pteryliae where their anlages had been formed at a later date, showed aberrations in their development (narrow vane with poorly linked barbs in the contour part), or else failed to develop at all, leaving the corresponding regions devoid of any plumage. To such regions belonged: the under part of the wings, partly the thorax, the hind limbs, the neck and the head. On the crown of the head there appeared a small number of deficient feathers in the shape of a crest (see figure). By the time when the control starlings had already entered their juvenile moult, the thyroidectomized birds did not shed their feathers yet. It may also be noted that, when applied at a later date, thyroidectomy failed to cause any essential deviation either in the rate, or nature of the formation of feather covering.

Aberrant characters could also be observed in the development of behaviour characters in the experimental young starlings. The latter are known to respond readily to a number of external stimuli, in particular, to sounds of thin tone. When these are applied, the birds make a peculiar tossing motion of their heads, gape and utter a loud cry. In thyroidectomized birds this general reaction which is typical to early stages, is preserved to a certain extent in subsequent stages

as well: the control birds have by this time entirely lost this reaction and responded to those stimuli by a negative reaction (timorousness). Young birds which have already completed their development are also somewhat lagging in the development of their reflectory functions. Thus, one of the operated starlings that had been brought up at the laboratory was able to fly, but considerably differed in this behaviour from the controls; the deficiency of its plumage was not the only cause responsible for this difference. This starling knew its name, and readily answered to calls, alighting on the arm of the calling person. But it lagged behind normal birds in picking up the feed and in other reactions.

Young starling (30 days of age) thyroidectomized two days upon hatching (Koltushi, 1938)

To sum up our observations it should be said that the rôle of the thyroid gland in the development of the young *Sturnus vulgaris* L. is different from the rôle this gland plays in the morphogenesis of the birds earlier investigated. There is scarcely any determination of the processes of general growth by the thyroid hormone, if at all. The high energy of growth in these birds seems to be determined not so much by the thyroid hormone as by some other, genetic factors. The processes of differentiation of the organism, of its coverings and behaviour, are largely determined by the degree of activity of the thyroid gland. If the hormone of this gland is lacking, the differentiation of the organism is suffering inhibition.

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ENDOCRINOLOGY

IMPORTANCE OF VITAMIN CONTENT IN FODDER FOR THE REPRODUCTIVE FUNCTION AND THE CONTENT OF PREGNANCY HORMONES IN THE BLOOD OF HORSES

By B. M. ZAVADOVSKY and E. G. NESMEYANOVA-ZAVADOVSKAYA

(Communicated by I. I. Schmalhausen, Member of the Academy, 27. VII. 1944)

During the summer of 1942 we carried out at the stud-farm No. 40 in the Omsk region research work on the application of hormonal diagnostics of pregnancy in mares, using the modified chicken comb test earlier proposed by us (1).

These researches enabled us to reveal manifold disturbances of sexual functions in the horse herds of the stud-farm, and among these considerable deviations in the normal content of the gonade stimulators in the blood of mares during pregnancy.

1. The stud-farm in question shows year after year a low rate of pregnancy in covered mares, generally not exceeding 70 per cent.

2. In July, 1942 (similarly to earlier years), *i. e.* by the end of the coupling season, there were no less than 14 mares that had not rutted at all since February, and an even greater number—about 30—which continued to repeat their sexual cycle without becoming pregnant in spite of repeated coverings (the so-called «repeaters» or «nymphomaniacs»).

3. In these circumstances prolan treatment according to the method proposed by Mirskaya and Petropavlovsky, which was applied by the farm administration remained without any noticeable effect. While under normal conditions the administration of prolan to mares at the moment of the natural appearance of rut, according to data reported by these authors, regularly results in a considerable rise of the per cent of ovulating and pregnant mares and in a shortening of the period of rut, in the case of our stud-farm only 22 out of 45 mares treated with prolan were fecundated. If we take into account the quite considerable number of repeated applications of prolan, fecundation in the course of the experimental interval was achieved only in 16 cases out of 59 applications of prolan, and in 43 cases they remained without effect.

4. At the same time we observed numerous marked deviations in the endocrine coefficients of the blood in a number of pregnant mares. 48 mares were tested by the hormonal technique at the period of maximum gonade stimulator content (in an overwhelming majority of cases this period lies between the 50th and 80th days after covering). In 12 mares, *i. e.* in 25 per cent of the total number tested, either no gonade stimulators were discovered though the mares were pregnant, or the coefficients of growth of the chicken combs were so insignificant that they supplied no grounds for a positive diagnosis of pregnancy, and so left the question open.

Thus, the blood of the mare «Murzilka» was tested for pregnancy hormones several times: on the 62nd day of pregnancy the test carried out on 2 chickens

gave no result: on the 79th day one of the 2 chickens showed after 5 days an increase in the size of its comb from 1.8 to 2.1 cm in length and from 0.5 to 0.8 cm in height; and the second, from 1.5 to 1.8 cm in length and from 0.5 to 0.6 cm in height, *i. e.* the reactions in both were not significant enough to draw a positive conclusion as to the pregnancy of the mare tested. Only the third test made on the 71st day produced a somewhat higher size increase: from 2.1/0.7 to 2.5/1.1, which made us grant the probability of pregnancy in the mare. Tests on other mares which later proved pregnant, showed no changes in the size of the chicken combs whatever, which normally should have increased in the course of 5 days by 1.5—2.5 cm in the sum of length and height.

5. On the contrary, in 6 cases mares which had produced a marked response in chickens in the form of comb increase and a general activation of the sexual system, proved dry. The mare «Kunitza» on the 83rd day after covering produced a comb increase after 5-day-growth from 2.5/1.0 to 3.3/2.0, *i. e.* of 2.2 in the sum of length and height. This mare was earlier repeatedly examined both rectally and by the method of Prof. Ivanov (chemical urine test), and was found pregnant. There can be no doubt that in this case there was an undoubted pregnancy followed by the resorption of the foetus and a protracted retention of gonade stimulators in the blood of the mare already sterile.

Another mare «Vstrecha» was covered for the last time on April 15. On the 10th of June it was examined rectally and recognized as undoubtedly pregnant. Between July 19 and 22, *i. e.* by the 93rd day of the supposed pregnancy of this mare, its blood produced a sufficiently marked effect on the chicken comb which increased from 2.5/0.9 to 3.0/1.3. On the 23rd of July this mare died of heart failure. No foetus was discovered at autopsy.

These two clearly established facts of protracted circulation of gonade stimulators in the blood of mares which have become barren, leave no doubts that in other cases we also had to do with a primary germination of the foetus and a subsequent latent abortion, or resorption of the foetus at some early stage of its development. The probability of a traumatic abortion in a third mare «Overture» is corroborated by its excessive exploitation during the summer period of farm work.

The fact of protracted circulation of gonade stimulators continuing in the blood of the mare after the loss of the foetus has been first reported by Becker. But as a group phenomenon forming a scientifically established source of errors in the application of the hormonal method of pregnancy diagnostics, a source of positive tests for pregnancy hormones in the absence of pregnancy, this fact has been encountered for the first time by us.

The opposite phenomenon, *i. e.* the absence of gonade stimulators in the blood in the case of certain pregnancy, has not been established, as a group phenomenon, by anybody else.

According to literary data, as well as to our own data obtained in past years, hormonal diagnostics of pregnancy in mares is characterized by an extremely high degree of precision, and the number of erroneous results generally does not exceed 1—2 per cent and only occasionally may be as high as 5 per cent.

This made us suppose that there must be in this case some common specific cause or causes, producing manifold disturbances in the sexual functions of the mares, and among these—disturbances of the normal production of pregnancy hormones.

On the ground of our analysis of the conditions under which the horses are kept at the stud-farm No. 40 we think it possible to conclude that the specific cause of the so greatly varying disturbances of sexual activity in this case is a developed chronic A and E hypoavitaminosis, characteristic of the nutrition conditions of the steppe zone of West Siberia.

1. During the period 1941—1942 as well as in the course of years preceding this period the stud-farm No. 40 has never lacked concentrated fodder, such as high grade oats, the horses were well-fed and their general condition left nothing

to desire. Thus, the factor of quantitative underfeeding must be absolutely excluded.

2. The botanic composition of the grass, naturally growing in the steppe zone of West Siberia and forming the chief source of green fodder during pasture time and of hay, is absolutely inadequate, under the conditions of an almost complete absence of intensive leguminous fodder crops and of tuber root plants, to supply horses of a high breed with the necessary quantity of vitamins. The circumstances are made still worse by unsatisfactory hay making, which does not provide for the preservation of vitamins in the hay. Chemical analyses of the best samples of hay used at the stud-farm No. 40, made at the Fodder Laboratory of the All-Union Institute of Horse-Breeding, have shown a very low carotin content of this hay: it was as low as 2—4 mg per 1 kg of hay, while the standard content of carotin in hay is 20 mg.

3. Only one year—1940—41—was registered in the course of the existence of the stud-farm No. 40, during which the per cent of successful couplings proved fully satisfactory and was as high as 89. This year is noted also as the year of an exceptionally bountiful grass yield; moreover, during the winter of 1940—41 the management of the stud-farm practised a regular addition of germinated wheat to the fodder. This is an additional evidence corroborating the correctness of our conclusion regarding the decisive significance of A and E vitamin supply, resp. of its lack, in this case.

4. The mass occurrence of foetus resorption described above fully corresponds to the physiological consequences of A and E avitaminosis, firmly established experimentally in laboratory animals.

Our general conclusion is that the cause not only of the low fecundation rate, but also of the high death rate among young in the steppe zone of West Siberia and North Kazakhstan is the deficient vitamin content of the fodder. This is confirmed by the observations of the greatest authorities of the American veterinary and zootechnical science. Thus, Prof. Dimock [4] says: «From what I have been able to observe and from what I have learned from others, I cannot help but feel that large areas in the south-eastern portion of the United States will never do well in the production of horses and mules and will never do too well in the maintenance of mature horses and mules until they have better pastures and grow more feed».

It seems to us that the conclusion drawn from what has been said above should be extended also to the necessity of a maximum development of fruit- and market-garden crops for human use in these districts and regions of the USSR.

This conclusion is confirmed by data testifying to the low qualitative activity of gonade stimulators in the blood of pregnant women in Omsk. We have reported earlier [5, 6] on the response in chicken combs by the injection of the blood of pregnant women, which consisted in their reddening and size increasing. In 1942 we repeated this test with samples of placental and retro-placental blood obtained at the Obstetric Clinic of the Omsk Medical Institute. None of the 10 samples tested, 7 of which were taken from cases in which the child was male, produced a marked effect in the chicken combs. There is every ground to regard this decrease in the activity of pregnancy in the blood of women in Omsk as a consequence of prolonged hypoavitaminosis resulting from a diet deficient in fruit and vegetables.

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EXPERIMENTAL MORPHOLOGY

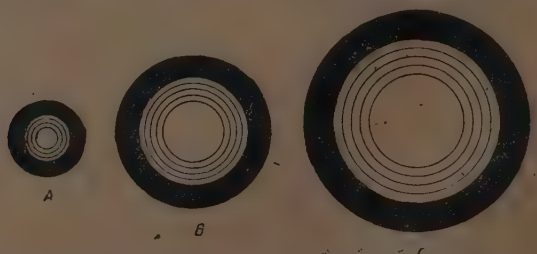
RATE OF EPITHELIZATION OF SKIN WOUNDS IN *AMPHIBIA*

By A. A. BRAUN and G. N. ORLOVA

(Communicated by A. A. Zavarzin, Member of the Academy, I. II. 1944)

The main purpose of this investigation was to study the dependence of the rate of epithelization of skin wounds upon the size of the wound surface and age of the animal. Accordingly, six-month, 1.5-year, and 3-year-old animals were used as a material for the present investigation. The experiments were carried out at room temperature. The wounds were inflicted with the aid of a special punch, securing the standard size of the wounds. Four punches were used: 8, 12, 16, 24 mm in diameter, respectively. Epithelial regenerates were well-noticeable owing to their pigmentation. Measurements were made daily under low magnification.

1. It was found that at early stages the epithelization rate was higher as compared with that at the more advanced stages of regeneration. (A) The axolotls were 3 years old. The wounds were 8 mm in diameter. Regeneration rate during the first day and the subsequent days was on the average 1.5 and 0.5 mm, respectively. (B) The axolotls were 3 years old. The wounds were 16 mm in diameter.



Schemes of epithelization of wound surfaces in wounds of different size. *A*, wound 8 mm in diameter. *B*, wound 16 mm in diameter. *C*, wound 24 mm in diameter. Black area epithelized during the first days. Concentric cycles denote areas epithelized during subsequent days

Regeneration rate during the first day and the subsequent days was to 2.5 and 0.7 mm in diameter, respectively. (C) The axolotls were of the same age. The wounds were 24 mm in diameter. The corresponding regeneration rate was equal to 3 and about 1 mm, respectively. A comparison of these data shows that the linear movement of regenerates during the first day was three times as high as during the subsequent days. However, it is more correct to characterize the regeneration rate not in the linear measures but in square units (Figs. *A*, *B*, *C*). Correspondingly,

data for the axolotls described will be as follows: (A) 30, 8, 5, 4, 3 and 3 mm^2 for the first, second, third, fourth, fifth and sixth days, respectively. (B) 101, 22, 18, 16 mm^2, *etc.*, for the first, second, third and fourth day, *etc.*, respectively. (C) 189, 51, 45, 39 mm, *etc.*, for the first, second, third, fourth day, *etc.*, respectively. These data allow to conclude that regeneration rate decreases according as wound epithelization proceeds. This was found to be true especially for earlier stages of regeneration.

2. The second conclusion to be drawn from these data is that epithelization proceeds at a higher rate in wounds of larger area. To illustrate this conclusion it is sufficient to compare the data bearing on regenerates for 8, 12, 16 and 24-mm wounds, say at the first day of regeneration. The linear and square values of regenerates are equal to 1.5, 2.0, 2.5, 3 mm, and 30, 60, 101, 189 mm^2, respectively. Comparing the data relating to regenerates for 8 and 16-mm wounds and those for 12 and 24-mm wounds, one may see that when the wound diameter is increased twice, and the area of the regenerate is increased four times, the surface epithelized increases approximately three times within the same period of regeneration. The epithelization proceeds from the edges of the wound. The edge of a 24-mm wound is three times that of a 8-mm wound: at the same time, the area epithelized in the first case is six times as large as in the second one during the first day of regeneration.

3. The results obtained for different skin regions (head, back, tail basement) revealed no regular and constant differences in the rate of epithelization of the wound surface.

4. The dependence of regeneration rate upon the age of the animal is, on the contrary, constant and fairly expressed. Two sets of experiments were carried out on axolotls 6-month, 1.5-year, and 3-year-old. The diameter of the wounds was 8 mm in all cases. In the first set of experiments the regeneration rate on the first day was on the average equal to 2.5—3, 2—2.5, and 1—1.5 mm for 6-month, 1.5-year and 3-year-old axolotls, respectively. In the second experiment the corresponding values were 4 and 1.5 mm for 1.5-year and 3-year-old animals, respectively. Epithelization was complete within two, three and five days in the first set of experiments, and within one and six days in the second set of experiments, respectively. These data show clearly that the epithelization rate decreases with age of the animal. In addition, it is necessary to take into account that younger animals have to epithelize a relatively more extensive area of body surface, if the wounds areas were made equal throughout the experiment.

5. Lastly, it was also important to study whether the regeneration rate of the same wound varies in case the epithelium is repeatedly removed. The experiments were performed on 6-month, 1.5-year, and 3-year old axolotls. 8-mm wounds were inflicted upon the head, back and tail regions. Some animals had 16-mm wounds in the head region. The wounds were inflicted repeatedly, up to 6 times, each of them being done just after epithelization of the wound was complete. The regenerate was removed up to the very edges of the wound.

24 animals out of 30 showed a similar rate of epithelization. 8-mm wounds in 6-month-old axolotl were epithelized within two days, both in the first and the repeated wounding. The epithelization rate in 16-mm wounds was equal to six days, both in the first and every subsequent operation. The epithelization rate for 1.5-year-old axolotls was found to be different, varying from 2 to 4 days for the first and for every subsequent wounding. The same was found to be true for 3-year-old axolotls. In this group the rate of epithelization was equal to 4, 5, 6, 7, 8 days, respectively, for the first as well as for every subsequent operation.

In two cases only the rate of epithelization for the first operation was somewhat higher as compared to subsequent operation. (1) One of these was a 6-month-old animal; the tail wound was 8 mm in diameter. The epithelization rate for the first operation was equal to 1 day, while every subsequent epithelization was complete in 2 days. (2) The second axolotl was 3-year-old, the back wound was 8 mm in diameter. The epithelization rate for the first operation was equal to 4 days as compared with 5 days for all the subsequent recoveries.

In a similar number of cases the epithelization rate for the first operation was, on the contrary, somewhat lower than that for each subsequent one. These were 1.5-year and 3-year-old axolotls; the wounds were 8 mm across in both cases. In the first case the regeneration rate for the first operation was equal to 4 days and for the second, recovery of the tail wound was equal to 5 days, as compared with 3 and 4 days, respectively.

At last, two cases were observed with a somewhat lower rate of epithelization for the second recoveries. These were 1.5-year and 3-year-old axolotls, the wounds were 8 mm in diameter in the dorsal region in either case. In the first case the regeneration rate for the second recovery was equal to 4 days, and in the second case the rate was equal to 5 days, as compared to 3 and 4 days for the first and second case, respectively.

The above data show that the deviations which are few in number, are quite insignificant, and the material considered gives every reason to conclude that regeneration rate of repeatedly removed epithelium (no less than 6 times) is subject to no variation. The significance of this conclusion is strengthened, moreover, by the fact that each subsequent regeneration process must lead to a decrease in the mass around the wound epithelium because of its shifting on to the wound surface. As a result the mechanical conditions of strain and pressure in the epithelial layer around the wound region must change. Nevertheless, in spite of the varying conditions the regeneration rate remains the same. This fact is i accordance with the view that epithelial cells actively move to the wound surfane, and contradicts the hypothesis of passive shifting of the epithelial layer from its cut edges, leading to a filling up of the epithelial defect.

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HELMINTHOLOGY

A CONTRIBUTION TO THE STUDY OF THE BIOLOGY OF *ORIBATEI* MITES, INTERMEDIATE HOSTS OF CESTODES OF THE FAMILY *ANOPLOCEPHALIDAE*

By A. P. SOLDATOVA

(Communicated by K. I. Skrjabin, Member of the Academy, 25. III. 1944)

As a result of studies carried out both by American and Russian scientists ([1–5]), soil-mites belonging to the group *Oribatei* have been found to be used up as intermediate hosts by various cestodes of the family *Anoplocephalidae*. Thus, the *Oribatei* participate in the development of representatives of the genera *Cittotaenia*, *Bertiella*, *Moniezia*, *Anoplocephala*, *Paranoplocephala*, and others.

Owing to these studies the investigation of the soil-mites (*Oribatei*) has become not only of purely scientific, but of economic interest, as well. It stands to reason that for its solution any problem connected with the epizootology and prophylaxy of anoplocephalidoses in domestic animals requires a thorough knowledge of the biology and ecology of the intermediate hosts of the corresponding nematodes.

However, the group of *Oribatei* as a whole has been but poorly investigated, and a number of questions bearing on the biology and ecology of soil-mites have not been discussed in literature.

The present study is devoted to one of the essential questions of the biology of *Oribatei*, *viz.* to the life-time of the sex mature stage of those mites. This question becomes of quite particular importance when studying epizootics caused by *Anoplocephalidae*, in so far as the mites become infested with eggs of cestodes during the imaginal stage of the former, and the period during which the pasture is subject to the anoplocephalidosis invasion depends upon the length of the sex-mature stage of the mites.

We studied the question for three species of mites which had previously been recorded as intermediate hosts of *Anoplocephalidae* parasitic of domestic animals: 1) *Scheloribates laevigatus*, 2) *S. latipes* (fam. *Ceratozetidae*) and 3) *Galumna obvius* (fam. *Galumnidae*). As material served newly hatched mites, grown from nymphs under laboratory conditions.

The experimental mites were kept in boxes 40×60 mm large, 10—25 individuals in every box. They were fed on decayed leaves of various trees, moss and rotten wood. Every 10—15 days the mother mites were transferred to boxes containing fresh feed; their state was examined on this occasion. As soon as the first dead individuals were revealed by examination, the latter was regularly made every 5th—10th day.

1. Experiments aimed at the determination of the life-time of the sex-mature stage of *Galumna obvius* were carried on with 70 individuals. The first two dead mites were discovered after 13 months of experiments; 5 mites perished after 14 months and 26 days; 4 mites, after 14 months and 27 days; 2 mites,

after 15 months; 30 mites, after 15 months and 1 day; 5 mites, after 15 months and 2 days; 12 mites, after 15 months and 3 days; and 10 mites, after 15 months and 5 days. Thus, the minimum life-time of the sex-mature stage of *Galumna obvius* has been found to equal 13 months; the maximum, 15 months and 5 days; and the medium, 14 months and 25 days.

2. The life-time of *Scheloribates laevigatus* was studied on 50 individuals. The first dead mites, 12 in number, were recorded after 15 months and 6 days; the remaining 38 individuals perished after 15 months and 17 days. Thus, the life-time of the sex-mature stage of *Scheloribates laevigatus* ranges between 15 months 6 days and 15 months 17 days, which makes an average of 15 months and 16 days.

3. Experiments on the species *Scheloribates latipes* involved 30 mites. The first 6 dead mites were discovered after 14 months and 27 days, the remaining 24 individuals perished after 15 months and 27 days. Hence, the minimum life-time of the sex-mature stage of *S. latipes* makes up 14 months and 27 days; the maximum amounts to 15 months and 27 days, which gives an average of 15 months and 21 days.

If we take into account that the larvae of various cestodes take up to 5 months and 20 days to attain the invasion stage in mites, we may safely infer that the invasion principle can be preserved during 9—10 months in a generation of mites belonging to the species here described.

It should be noticed here that the development of the pre-imaginal stages of oribatides (egg, larva, nymph of the 1st stage, nymph of the 2nd stage and nymph of the 3rd stage) proceeds on the average during the following periods: 97 days in *Scheloribates laevigatus*; 84, in *S. latipes*; 109, in *Galumna obvius*. These data have been obtained by the author as a result of individual keeping of the mites in special wax chambers throughout their pre-imaginal period, at a temperature of 18—23° C.

Thus, summing up data on the mean life-time of mite imagoes we arrive at the conclusion that the total life-time of oribatides (from the egg and to the death of sex-mature individuals) makes up for *Galumna obvius* 19 months and 14 days; for *Scheloribates laevigatus*, 18 months and 10 days; for *S. latipes*, 18 months and 28 days.

Such a long period of life of the oribatides is undoubtedly one of the factors contributing to the accumulation of huge numbers of soil-mites in nature. Thus, according to data by Baskina and Fridman ([6]), the oribatides constitute about 70 per cent of the total mite population of the humid meadows of the Molotov department. Their average number was found to attain 2460 individuals per one square metre. According to data by Boitzova ([7]), the number of oribatides in lichen forests of the same department made up 77 per cent to the total invertebrate fauna, and 92 per cent to the total number of mites, amounting to an average of 37870 individuals per one square metre area.

It is thus evident that the extreme abundance of oribatides in nature, on the one hand, and the longevity of their sex-mature stage, on the other, contribute to the accumulation and stability of anoplocephalidosis invasions at territories allotted to pastures.

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